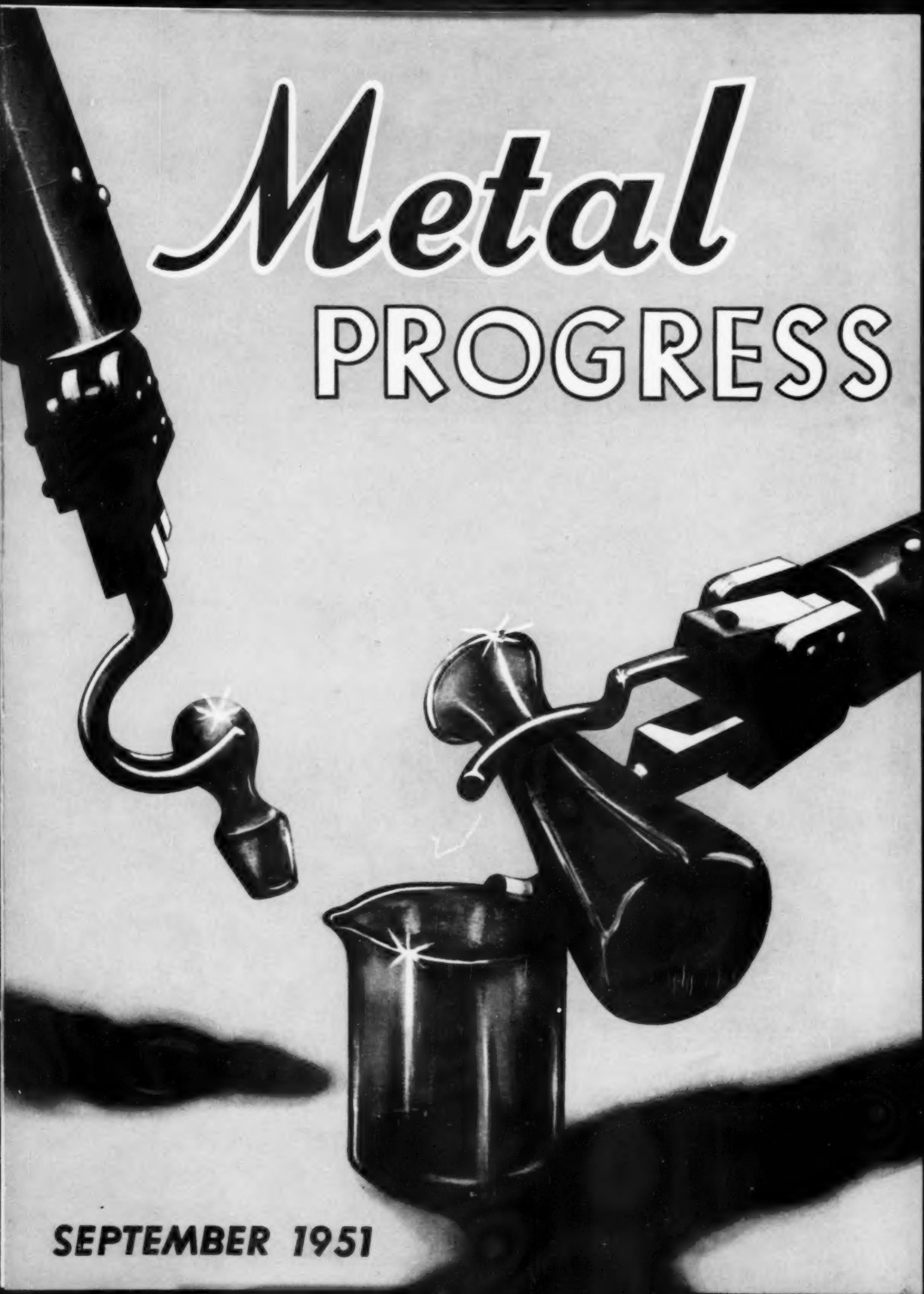
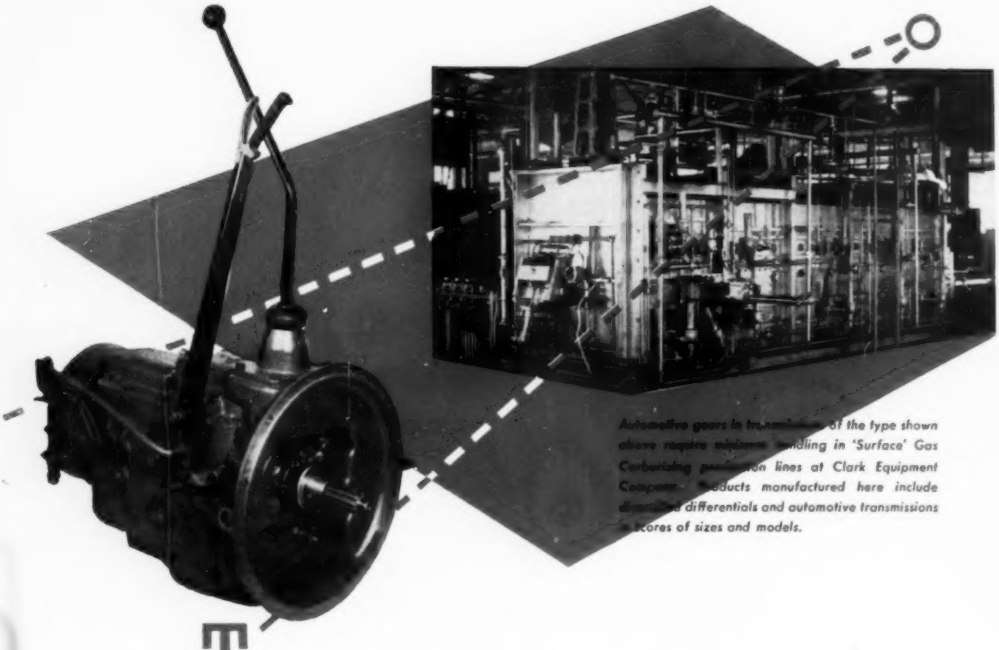
Metal PROGRESS



SEPTEMBER 1951



Automotive gears in transmissions of the type shown above require minimum handling in 'Surface' Gas Carburizing production lines at Clark Equipment Company. Products manufactured here include diversified differentials and automotive transmissions in scores of sizes and models.

Transmission Parts are *Gas Carburized* in a 'Surface' Continuous Furnace... on a job-shop basis!

Practically all major transmission manufacturers heat treat their component parts in 'Surface' furnaces. Why? Take the Clark Equipment Company, Jackson, Michigan, as an example.

Despite variations in size, shape and metal of parts to be treated, Clark engineers wanted heat treat equipment that afforded flexibility on a job-shop basis, with close control, minimum rejects, dependability, economy, and lasting stamina.

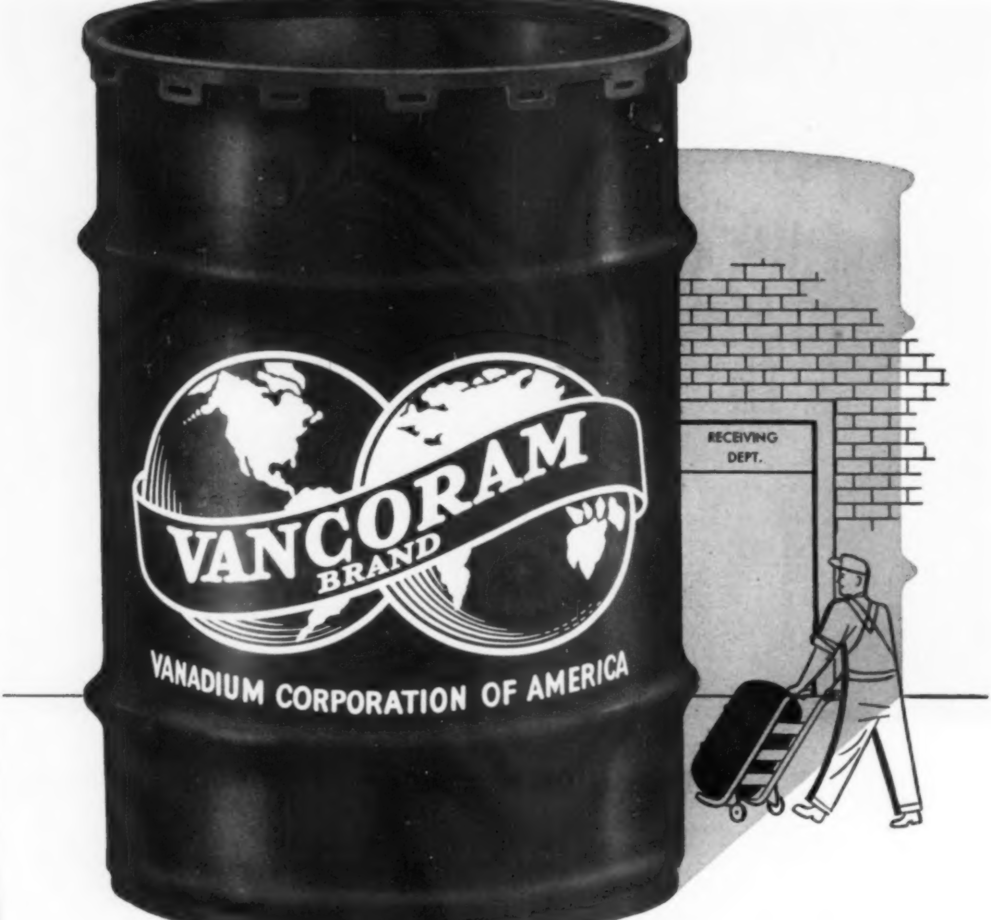
Today, by carburizing 14 component parts in either of two 'Surface' 3-row tray-pusher type, Radiant Tube furnaces with RX gas atmosphere, Clark Equipment Company produces rugged, durable automotive transmissions.

Gears and mainshafts of Clark transmissions are made of fine grain alloy steel (8620) and carburized to the case depth specification of .035''-.050'' at a temperature of 1675 F. They are then quenched direct into 170-180 F. oil, washed, and tempered at 325 F. for one hour at temperature. Furnaces afford a total capacity of 1500 lb/hr., near elimination of distortion and a high degree of uniformity within very rigid manufacturer's specifications.

This example is typical of the extreme flexibility of production line operations possible with 'Surface' furnaces. Ask your 'Surface' engineer for more details or write for bulletins covering heat treatments of interest to you.

'Surface'
INDUSTRIAL FURNACES

SURFACE COMBUSTION CORPORATION, TOLEDO 1, OHIO



The world is at your doorstep

When you see the VANCORAM trademark you can be assured of the highest quality products it is possible to produce.

The world is truly at your doorstep, for the finest raw materials from the world over contribute to the uniformity, superior quality and maximum efficiency of VANCORAM products.

To make it easier for you to identify these fine products, shipping drums are now painted a distinctive green with the VANCORAM trademark superimposed in white—your assurance of top-notch quality.

MAKERS OF ALLOYS
VANCORAM
CHEMICALS AND METALS

VANADIUM CORPORATION OF AMERICA

420 LEXINGTON AVENUE, NEW YORK 17, N. Y. • DETROIT • CHICAGO • CLEVELAND • PITTSBURGH

Metal Progress is published and copyrighted, 1951, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

paper sculpture by [illegible]

EFFICIENCY IS INHERENT

in **NIALK*** *TRICHLORethylene . . .*

processed to assure highest purity and uniformity

in metal-cleaning and degreasing.

NIAGARA ALKALI COMPANY

60 East 42nd Street, New York 17, N. Y.

Liquid Chlorine • Caustic Potash • Carbonate of Potash • Paradichlorobenzene • Caustic Soda
TRICHLORethylene • NIAGATHAL* (Tetrachloro Phthalic Anhydride)

*Trade-mark

Who gains by the incentive system?

WASHINGTON STEEL CORPORATION, Washington, Penna.
manufacturers of *MicroRold* stainless steel sheets and strip

Performance data, based on production experience, available upon request from authorized firms or individuals for heat treating any of the following items:

NEUTRAL HARDENING

- ☐ AIRCRAFT [illegible] gears ☐ propeller gears ☐ propeller hub parts ☐ [illegible] ☐ drag links ☐ piston rings ☐ engine parts ☐ supercharger parts ☐ engine cylinder liners, etc.
- ☐ TANK piston rings ☐ cylinder liners ☐ engine exhaust valves ☐ engine cam shafts ☐ gears, etc.
- ☐ Armor piercing shot and caps
- ☐ Armor plate ☐ Land mine parts
- ☐ Jet engine bearing races

DRAWING

- ☐ AIRCRAFT gas turbine gears ☐ landing gears ☐ piston engine parts ☐ supercharger parts, etc.
- ☐ Armored vehicle gears & pinions
- ☐ Armor piercing shot
- ☐ Tank torque convertor parts
- ☐ Land mine parts
- ☐ Shells (cold extruded) ☐ cold drawn
- ☐ Tank tread pins

SOLUTION HEAT TREATMENT OF ALUMINUM

- ☐ [illegible] ☐ airframe parts ☐ rivets ☐ plane rudders ☐ engine cowls ☐ helmets

ANNEALING

- ☐ [illegible] extruded or cold drawn
- ☐ Cartridge cases—brass or steel
- ☐ Copper rotating bands
- ☐ Jet engine compressor parts ☐ silver lined bearings, etc.
- ☐ Aircraft engine connecting rods

AUSTEMPERING

- ☐ 3.5" [illegible] motor bodies
- ☐ Rocket motor bodies
- ☐ Automatic pistol parts
- ☐ Nose detonator fuses
- ☐ Bomb nose fuses
- ☐ Aircraft & tank piston rings
- ☐ Bomber plane brake shoes
- ☐ Spring clips

CYCLIC ANNEALING

- ☐ 3.5" bazooka motor bodies
- ☐ Shells (hot forged)

CARBURIZING

- ☐ [illegible] turbine gears
- ☐ Tank bogie wheel parts
- ☐ Tank engine gears
- ☐ Aircraft piston engine parts
- ☐ Aircraft camera parts
- ☐ Armor plate
- ☐ Gun breech block parts

MARTEMPERING

- ☐ [illegible] gun parts
- ☐ 40-mm bofors gun parts
- ☐ Tank engine camshafts ☐ engine gears ☐ armor plate ☐ torque convertor parts ☐ tread pins, etc.
- ☐ Aircraft gas turbine gears ☐ clutch rings
- ☐ Armor piercing shot
- ☐ Rocket [illegible]

HEATING FOR FORGING

- ☐ 3.5" bazooka motor bodies
- ☐ Shells (hot nosing)

DESCALING

- ☐ Aircraft gas turbine buckets
- ☐ Stainless aircraft engine parts
- ☐ Inconel aircraft engine parts

Check

YOUR HEAT TREATING PROBLEM FOR NATIONAL DEFENSE

. . . AJAX Has the Answers!

4 out of 5 metal products for defense use can be heat treated better, faster, with less floor space and at lower cost with an Ajax Salt Bath Furnace than by any other method! This statement is proved by the widespread use of Ajax furnaces during World War II and by the even more marked trend toward this exclusive salt bath method in today's rearmament program. And we'll be glad to prove it *specifically* by heat treating specimen batches of your materials under actual shop conditions in the Ajax Metallurgical Service Laboratory. There is no obligation on your part. You be the judge!

Ajax Submerged Electrode Furnaces*, equipped with refractory pots, reduce maintenance costs to the vanishing point because pot and electrode life is *measured in years.*

**Patented in U.S. and foreign countries.*

Over 3,000 installations—more than all other electric salt baths combined.

See us at the Metal Show—Booth F-421

AJAX ELECTRIC COMPANY, INC.

World's largest manufacturer of electric heat treating furnaces exclusively

910 Frankford Avenue, Philadelphia 23, Pa.

IN CANADA: GENERAL ELECTRIC CO., LTD., TORONTO, ONT.

AJAX ELECTRIC SALT BATH FURNACES

"So satisfactory we've ordered another"

"Our Westinghouse Furnace has proved so satisfactory that we've ordered another one", says Marlin-Rockwell Corporation, Plainville, Connecticut—manufacturer of ball bearings.

"The furnace has resulted in at least 50% improvement in the production-per-man-hour ratio over the system we previously used. Controlled feeding of small bearing rings and retainers permits gradual heating. This, along with controlled temperature of the quenching bath, practically eliminates distortion.

"Proper atmospheric control provides the right bright-hardening, entirely eliminating sandblasting. Our bearings have a better finish, and are a better product."

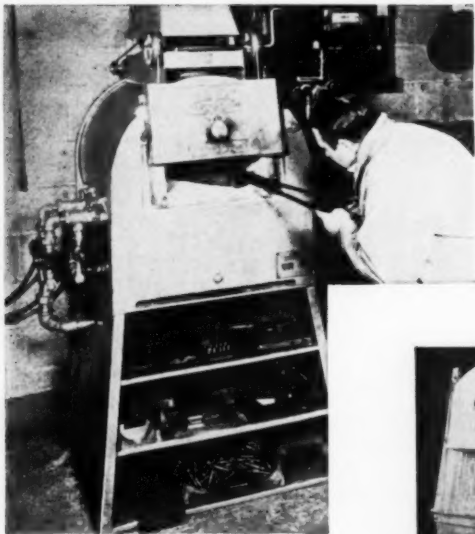
Gas-fired or electric, there's a Westinghouse Furnace to meet every heat-treating need. Westinghouse Electric Corporation, Industrial Heating Works, Meadville, Pennsylvania. J-10368

IF YOUR PRODUCT CALLS FOR HEAT-TREATING . . . IT CALLS FOR A WESTINGHOUSE FURNACE . . . GAS OR ELECTRIC

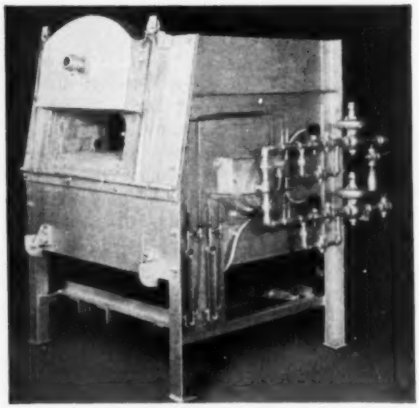
YOU CAN BE SURE... IF IT'S

Westinghouse

HEAT-TREATING FURNACES



SUNBEAM STEWART Industrial Furnace Division of Sunbeam Corporation builds this gas-fired oven furnace for tool rooms and shops. It operates over a 300-2400° F range, and employs an unusual semi-muffle which can be converted to a full muffle for atmospheric hardening. CARBOFRAX shapes are used for this muffle to secure faster, more uniform heating and to resist abrasion and heat shock.



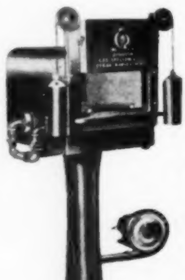
DEMPSEY INDUSTRIAL FURNACE CORP. builds this gas-fired atmospheric-type furnace which operates at temperatures as high as 2400°F. In this furnace the muffle is of CARBOFRAX material to improve the uniformity of treatment, secure maximum production and to minimize maintenance and replacement expense.

You will find *Super* Refractories in almost all heat-treating furnaces

Most builders of heat-treating furnaces agree that somewhere in almost every furnace Super Refractories can be used to advantage.

CARBOFRAX silicon carbide material, for example, is an excellent conductor of heat. Used for muffles or hearths, it means faster heat flow, more uniform heating—with an improvement in quality of treatment and usually with a saving in fuel. It is also outstanding in resistance to abrasion and heat shock.

There are other Super Refractories by CARBORUNDUM, each with distinctive properties. All are covered in a 40-page booklet, "Super Refractories for Heat Treatment Furnaces." May we send you a copy?

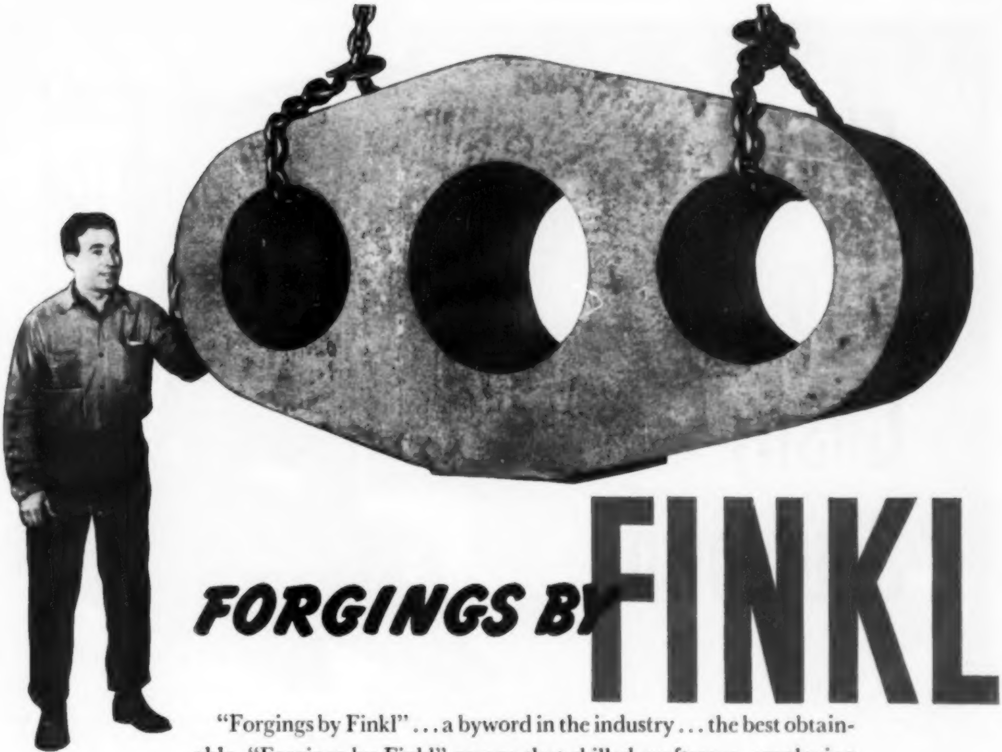


JOHNSON GAS APPLIANCE CO. manufactures this gas-fired furnace which is especially designed for heat-treating small tools, dies and other small parts. It is used for temperatures up to 2400°F. In this furnace the hearth is of CARBOFRAX tile which transmits heat rapidly and evenly to the work—and resists the abrasive action of the charge.

THE CARBORUNDUM COMPANY

Dept. C-91, Refractories Div. — Perth Amboy, New Jersey

"Carborundum" and "Carbofrax" are registered trademarks which indicate manufacture by the Carborundum Company



FORGINGS BY FINKL

"Forgings by Finkl" . . . a byword in the industry . . . the best obtainable. "Forgings by Finkl" means that skilled craftsmen, employing modern methods and machinery, have selected the best steel for the job and created the best job from the steel. And to doubly insure long life and economical performance, each step in the development of the forging is thoroughly checked metallurgically. Nothing is taken for granted.

A medium size forging, illustrated above, is the top head for a 2,000 ton hydraulic press. It is made of C-1045 steel, normalized and drawn in one of Finkl's heat treating shops. Forged from a 59" ingot, the rough machined forging shown weighs 22,800 pounds. Whether carbon or alloy steel, the Finkl organization can easily handle any job from a few pounds up to 50,000 pounds apiece.

Write or phone when you are ready to talk about or plan your forgings. The experience of Finkl Sales Engineers is available to you.

MANUFACTURERS OF THE LARGEST FORGINGS IN THE MIDDLE WEST

A. Finkl & Sons Co.

2011 SOUTHPORT AVENUE • CHICAGO 14

DIE BLOCKS & INSERTS • PISTON RODS & RAMS • SOW BLOCKS • CRANKSHAFTS

"EDCO Dowmetal BOTTOM BOARDS have resulted in tremendous savings for our foundry"

... says M. C. Crawford of RILEY STOKER CORPORATION

RILEY STOKER CORPORATION
FUEL BURNING AND STEAM GENERATING EQUIPMENT
101 WALKER STREET, DETROIT 7, MICH.

Christiansen Corporation
1515 North Kilpatrick Ave.
Chicago 51, Illinois

May 16, 1951

Attn: Mr. Edw. S. Christiansen, Pres.

Gentlemen:

Before the purchase of EDCO Dowmetal Bottom Boards, we made our own wood boards at a cost of approximately 70c each. We would make 5,000 to 6,000 per year and ended up with a poor quality board. They were much heavier than EDCO magnesium boards, not as easy to handle on the line, and our losses due to burning and breakage were 60 to 80% per year.

In three years time, we have purchased 1,700 of your boards at a cost of $7,585.00 and our loss in this period has been only $207.36 or 2.73%.

EDCO Dowmetal Bottom Boards have resulted in tremendous savings for our foundry. It is a pleasure to recommend them to other foundries.

Yours very truly,
RILEY STOKER CORPORATION
M. C. Crawford
M. C. Crawford
Director of Purchases
Detroit Plant

Above photo shows molder at Riley Stoker Corporation placing EDCO Bottom Board on flask preparatory to pressing. EDCO DOWMETAL magnesium boards maintain high quality of castings and reduce rejects because the exclusive grooved and vented design permits escape of gasses and insures mold stability.

Riley Stoker Corporation is one of the three largest manufacturers of steam generating and fuel burning equipment in the country. EDCO DOWMETAL Bottom Boards are used exclusively in their foundry in the production of gray iron and alloyed casting components.

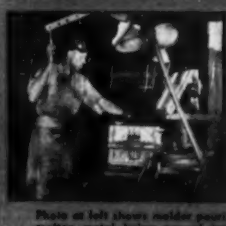


Photo at left shows molder pouring sand into flask. Photo at right shows molten metal being poured into molds which rest on EDCO Bottom Boards. Gravity conveyor line carries molds on for further processing.

Progressive foundry operators, like Riley Stoker Corporation, are equipping their foundries with EDCO DOWMETAL Bottom Boards.

Made of magnesium, these boards will not warp or break. There are no nails to come out, nothing to break or split—no upkeep! So durable, they can be considered permanent equipment. The many advantages from the use of these boards are effective immediately on their installation.

Write us or phone CApitol 7-2060 today for complete price schedule and list of 74 standard sizes available from stock.

EDCO
CHRISTIANSEN CORPORATION

CHRISTIANSEN CORPORATION
1519 N. KILPATRICK AVE. • CHICAGO 51, ILLINOIS
ALUMINUM ALLOY INGOTS • ZINC BASE DIE CASTING ALLOYS

SAVE SHOP LABOR SHOP TIME GRINDING COSTS

ELIMINATE THE GRINDING OPERATION ON YOUR STEEL BARS WITH

GROUND and POLISHED

STRESSPROOF

SEVERELY COLD-WORKED FURNACE-TREATED STEEL BARS

STRESSPROOF PROVIDES

4 QUALITIES IN 1 BAR

1. Eliminates Heat Treating

Its *in-the-bar* strength, as received, is twice as great as ordinary cold-finished steel shafting.

2. Eliminates Case Hardening

Its resistance to wear, as machined, is sufficient to replace many heat-treated or carburized steels.

3. Minimizes Warpage

Because it is *stress-relieved*, this superior bar assures the user a minimum of distortion.

4. Speeds Up Machining

Has *in-the-bar* machinability fully 50% better than heat-treated alloys of the same hardness.

Many companies are realizing important savings by using Ground and Polished STRESSPROOF bars instead of grinding the steel in their own shop. For this superior steel provides precision tolerances at a reasonable cost, without tying up valuable labor and machinery.

This all-purpose bar stock is ground to close tolerance and highly polished at the LaSalle plant on batteries of modern machines — at lower cost than you can grind it yourself. Furthermore, because this versatile steel is stress-relieved, it requires no straightening after keyseating, journaling, threading, or other machining operations. And its four qualities in-the-bar eliminate many other costly operations.

Almost all of today's Ground and Polished STRESSPROOF production is going into defense jobs. However, from time to time, some sizes of sample bars may be available for testing purposes.

LaSalle STEEL CO.

1424 150th Street, Hammond, Indiana

How the RCA *electron microscope* helps

INTERNATIONAL HARVESTER

make better equipment

IH can now forecast . . . with high accuracy . . . the behavior of metals used in building equipment for long and satisfactory service.

Here is how IH research men go about it.

With the RCA Electron Microscope, they observe the minute particles in the metals. They study the effect of carbide particle size on metal properties, make quantitative volume studies of different phases, analyze the structural changes accompanying the tempering of martensite—*and uncover new important and essential facts that help solve many manufacturing problems in the laboratories and factories!*

Consider the possibilities of this powerful instrument in your own research and production operations. You can obtain sharp images at direct magnification from 500 to 23,000 diameters, with photographic enlargements up to 100,000 diameters. You can resolve detail from 20 to 50 times finer than the best light microscope. You can bring every level of the specimen into sharp focus—regardless of the magnifying power you choose. You can also employ this versatile instrument for electron diffraction studies.

For complete data, write Dept. 72 U, RCA Engineering Products, Camden, N. J.

RCA

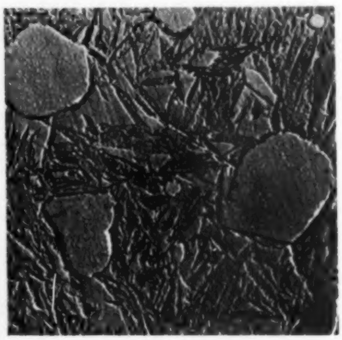
SCIENTIFIC INSTRUMENTS

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

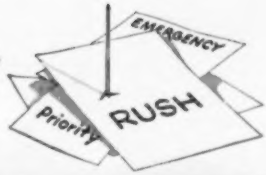
In Canada: RCA VICTOR Company Limited, Montreal

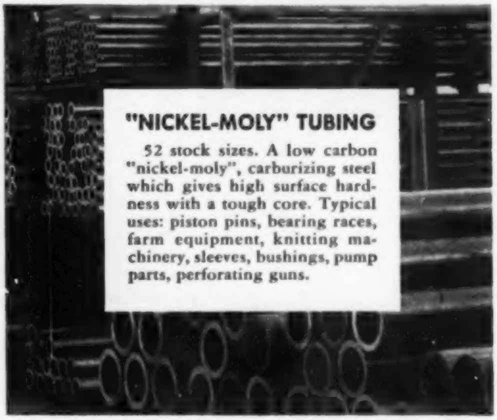
IH researcher observing a sample of steel in the RCA Electron Microscope. This instrument aids him in measuring carbide particle size and distribution—to predict the performance of the metal!



2.2% carbon, 12% chromium tool steel—magnified 7000 x by the RCA Electron Microscope. The approximately round islands are carbides; the irregular islands are austenite; the somewhat rough surface comprises martensite. The specimen was mechanically polished and etched with 4% picral. A replica was made of Formvar, then shadowed with chromium.

Tight steel supply got you in a pinch?





These two TIMKEN® steels will do 90% of your hollow parts jobs

and are available now in warehouse lots!

IF rush jobs find you short of steel tubing, get in touch with the Timken Company. The two Timken® steels described above—52100 tubing and "Nickel-moly" tubing—will do 9 out of 10 of your hollow parts jobs. And we guarantee shipment of warehouse lots within 24 hours after receipt of order.

We maintain a mill stock of 101 sizes of 52100 tubing—from 1" to 10½" O.D. This analysis is through-hardening in moderate sections. It can be heat treated to file hardness and tempered back to any point you want. There are 52 stock sizes of "Nickel-moly" tubing—from 1⅜" to 10¼" O.D. With heat treatment, it develops exceptional shock absorbing qualities.

Uniformity in every shipment is assured by the Timken Company's complete, rigid quality control from melting through final inspection. For the current mill stock list, write on your company letterhead to The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing

Engineering Digest

OF NEW PRODUCTS

SPOT WELDING AND SOLDERING MACHINE: A new welding and soldering machine by Joyal Products is of particular interest to the manufacturer of small products. It solders or welds in less than a second. It spot welds steel parts up to 3/32 in., and will solder brass up to 1/8 in. thick, as well as sterling silver and other precious metals. An automatic cut-off timer regulates soldering time. Heat control with eleven adjustments determines correct heat for the job. When dials are set, uniform soldering time, heat, and holding pressure on the electrodes are maintained, regardless of how long the foot switch is held down.
For further information circle No. 268 on literature request card on p. 32B

HIGH-VACUUM PUMP: A new microvac pump has been put on the market by the F. J. Stokes Machine Co. It has a capacity of 500 cu.ft. per min. and is suitable for any type of vacuum processing work. A water-cooled unit which operates at 390 rpm. with a top-mounted 25-hp. motor, it weighs 2400 lb. and is 76 in. high. It operates at a high volumetric efficiency because there is a complete discharge of air at each stroke, with no chance for re-expansion. With only four moving parts and low relative surface motion of piston to housing, minimum wear and low upkeep can be expected.
For further information circle No. 269 on literature request card on p. 32B

LABORATORY APPARATUS: RCA announces a low-cost unit to speed preparation of shadow-cast specimens for the electron microscope. The apparatus permits laboratory personnel to deposit a thin coating of tungsten, molybdenum or other suitable material by evaporation on as many as six glass microscope slides at one loading in the all-metal vacuum chamber. The unit consists of a small steel vacuum chamber which is evacuated at high speed by an oil diffusion pump, backed by a mechanical fore pump. The entire unit, with the exception of the fore pump, is contained in a steel cabinet 14 by 14 by 10 in. and weighs only 40 lb. The power requirement is 700 watts at 105-125 volts, 60 cycles.
For further information circle No. 270 on literature request card on p. 32B

SOLVENT CLEANER AND ADDITIVE: The Magnus Chemical Co. has announced that Magnusol, an emulsifiable solvent cleaner, can also be used as an additive to forming, cutting and stamping oils to act as insurance that the existing cleaning method will continue to do the job expected of it, regardless of any changes made in the formula of the lubricating compounds.
For further information circle No. 271 on literature request card on p. 32B

SHEET METAL TESTER: J. Arthur Deakin & Son are introducing G. H. Alexander's tester for making the Erichsen test for workability and fracture of sheet metal. It will handle material up to 5/64 in. thick. In testing, readings accurate to 0.0004 in. are obtainable. Test pieces 3 1/8 in. square and strips up to 2 1/16 in. wide can be tested with standard tools. Additional interchangeable tools can be supplied for checking narrow strips.
For further information circle No. 272 on literature request card on p. 32B

VERNIER POWER FEED: The DoAll Co. announces an improvement of power feed control on their hydraulically operated band tooled machine which will give the operator more sensitive control of the hydraulic table when sawing thick steel sections or when line grinding or diamond-sawing hardened alloys. The table in-feed knob has an added vernier control at the side which enables the operator to start a cut with a low feed rate.
For further information circle No. 273 on literature request card on p. 32B

FLAT WIRE PREFORMS: Flat wire "No-Tangle" notched-coil stress-relieved silver brazing and soldering rings for faster, more economical and improved brazing of armed forces projectiles and other ordnance equipment and supplies are now available from the Lucas-Milhaupt Engineering Co. These flat wire preforms were especially designed for applications requiring larger volume of silver alloy for added strength in critical joints and where the depth and shape of the groove prohibited use of round wire rings. Flat wire rings can be made in unlimited, job-determined diameters and wire thicknesses in butt, lap and gap form. Because they are flattened to individual job specifications, new rings provide a more complete fill and a stronger, leak-proof bond. Stress-relieved rings retain a plus and minus 0.001-in. tolerance under all conditions and do not distort or fall away from the workpiece when heat is applied. Stress relieving permits gap rings to be compressed easily into grooves in inner diameter applications. Released, they expand automatically to specified diameter. Lap and butt rings are designed for close tolerance applications on keyed and nonkeyed outer surfaces.
For further information circle No. 274 on literature request card on p. 32B

Engineering Digest

OF NEW PRODUCTS

ISOMA HARDNESS TESTER: The Cosa Corp. is introducing in the United States the Isoma tester for measuring Vickers hardness on small round and flat metal parts, foil, tinplate and other materials. This tester

has an automatic weight selecting device for applying dead weight loads from 50 to 1000 g. The minimum thickness of flat pieces to be tested is 0.0005 in. Minimum diameter for rounds is from 0.003 to 0.005 in. Standard equipment includes optical measuring system, transformer for 110 or 220 volts, base plate, test block, spare bulbs and table of equivalent values. Special supports and clamps are available for holding thin material and extremely small parts.

For further information circle No. 275 on literature request card on p. 32B

ARC DRIVE CONTROL: Westinghouse Electric Corp. now has available an arc drive control to produce electrical transient characteristics desirable for certain welding operations. The device operates automatically and instantaneously to provide an extra surge of welding current at the moment the arc becomes shorted. The extra surge of current helps clear the arc path and prevents arc outage or sticking of the electrode. The amount of arc drive desired can be set by the operator and a self-heating thermostat in the arc drive circuit protects it from overheating.

For further information circle No. 276 on literature request card on p. 32B

SOLVENT CLEANER: Du-Lite Chemical Corp. announces the development of a new soak solvent. Designed specifically for a quick removal of buffing and drawing compounds from knurled or fluted surfaces of all metals, it will also remove greases and oils in less than a minute and also can be used for preparing metal surfaces prior to plating, painting, parkerizing, bonderizing and galvanizing.

For further information circle No. 277 on literature request card on p. 32B

ELECTRONIC MICROMETER: Rapid and accurate measurements to a tolerance of 0.00002 in. are claimed for the Carson-Dice electronic micrometer manufactured by the J. W. Dice Co. An electronic circuit used in conjunction with an extremely accurate micrometer head permits "pressureless" measurement and eliminates "feel" as a source of error. The electronic circuit is sufficiently sensitive to give positive on-and-off indications with only five millionths of an inch displacement at the contact. The micrometer can be used for rapid measurement of machined parts, ball bearings, small assemblies and depths of counterbore. It can also be used to measure deflections in diaphragms, bimetal elements, springs, bellows and similar applications.

For further information circle No. 278 on literature request card on p. 32B

TEMPERATURE CONTROL: The Model V-1C Water, Vapor and Dust-Tight Temperature Control is an-

nounced by the Burling Instrument Co. Interchangeable with other instrument heads, it can be supplied for any temperature from minus 200 to 1400° F. with standard tubes and up to 1800° F. with special tubes. It can be supplied with either microswitches or manual reset switches.
For further information circle No. 279 on literature request card on p. 32B

ELECTRO-MECHANICAL MEASURE: W. C. Dillon & Co. announces an improved system for measuring tension, weight or tractive loads remotely. It is electro-mechanical in

design and is now equipped with oversize selsyn motors for added torque and increased dependability. Either one or two repeater stations may be used with each transmitter dynamometer as desired. Distance between each repeater can be varied. It has twelve different capacities from 0 – 500 lb. up to 0 – 50,000 lb.
For further information circle No. 280 on literature request card on p. 32B

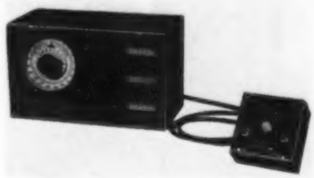
THICKNESS TESTER: The Audigage, a portable, self-contained thickness tester, is announced by Branson Instruments, Inc. It can be used to measure steel thickness over a range of $\frac{1}{16}$ to 12 in., from one side only. It does this by determining the frequency of vibration in the thickness direction. This property is essentially independent of the other dimensions of the material. Designed for one-man operation, the instrument has a conversion scale concentric with the frequency scale and enables the operator to read thickness directly in terms of frequency.
For further information circle No. 281 on literature request card on p. 32B

NEW CONTROL: A new instrument, combining the advantages of pneumatic control and having a calibrated chart 120 ft. long and 11 in. wide, has been developed by the Brown Instruments Div. The new instrument is an electronic potentiometer that has a 10% proportional band, a 150% proportional band and manual reset, or a 150% proportional band and automatic reset.
For further information circle No. 282 on literature request card on p. 32B

HEATER: The Brown Fintube Co.'s Type 102 Direct Fired Heater consists of a stainless steel outer shell with expansion section and an Inconel center tube with integrally welded extended surface nickel fins. Designed for high fuel and thermal efficiency, the equipment will heat air, special atmospheres, gases or liquids without contaminating them with the products of combustion. With an accurately controlled temperature range to 1600° F., the heaters use either gas or oil as fuel.
For further information circle No. 283 on literature request card on p. 32B

WELDING RODS: Silicon-free, flux-coated aluminum welding rods for oxy-acetylene and oxy-hydrogen welding have been released by the Eutectic Welding Alloys Corp. Manufactured in $\frac{1}{8}$ and $\frac{3}{32}$ in. diameters, the rods can be used in applications where an anodized silicon-bearing welding rod has produced an objectionable dark weld.
For further information circle No. 284 on literature request card on p. 32B

CONTINUOUS SAMPLING MONITOR: A new electrical device, perfected by General Electric Co., eliminates the complexity of paper work inherent in the continuous sampling methods of quality control. In opera-



tion, a given number of consecutive acceptable units is established by 100% inspection. This "clearance number" and the percentage number to be used for sampling are determined by the desired average outgoing quality level (AOQL) selected from a set of curves supplied with the equipment. Once the clearance number is reached, the operator begins sampling and continues until an unacceptable unit is found. This defective unit is replaced by a good unit and the 100% inspection is followed for another clearance.
For further information circle No. 285 on literature request card on p. 32B

What's New

IN MANUFACTURERS' LITERATURE

286. Alloy Steel
Booklet on Carilloy steel tells how No. 4150 and others provide toughness, strength and light-weight durability under trying conditions of service. *U. S. Steel Co.*

287. Alloy Steel
Booklet on the selection of the proper alloy steel grades for each manufacturer's needs. Write for "Wheelock, Lovejoy Data Book". *Wheelock, Lovejoy & Co.*

288. Alloy Steel
New 16-page, pocket-size booklet entitled "Republic Alloy Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

289. Alloys, Fabricated
Catalog available showing cost-cutting fabricated heat treating equipment for higher payloads and better quality. *Rolock, Inc.*

290. Alloys, Nickel
Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hardfacing. Booklet, "Hastelloy Nickel-Base Alloys", gives full details. *Haynes Stellite Co.*

291. Aluminum
Copy of "Alcoa Aluminum Impact Extrusions" will be sent on request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

292. Aluminum Forgings
To help you in designing for aluminum forgings, a new book is offered, covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Also a section on metallurgy gives all commercial alloy compositions, physical properties and tolerances. *Aluminum Co. of America.*

293. Aluminum Welding
New control system that extends electrode life for spot welding aluminum, fully described in "Technical Advisor No. 15". *Reynolds Metals Co.*

294. Arc Welding
Heliwelding, Airco's inert, gas-shielded arc-welding process for all-position welding of aluminum, magnesium, stainless steel, brass and copper, is fully described in ADC-709 Catalog 9. *Air Reduction Sales Co.*

295. Belts, Metal
Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

296. Brass and Bronze
8-page illustrated booklet on control methods as applied to brass and brass rod, forgings, die castings and welding. *Titan Metal Mfg. Co.*

297. Brinell
Bench model Brinell hardness tester (Model J) is illustrated and described in bulletin. *Steel City Testing Machines, Inc.*

298. Camera, High Speed
"Magnifying Time", a new folder describing high-speed camera capable of 1000 to 3000 pictures per second. Particularly adaptable for close inspection in machine tool operations and also for measuring flow of liquids as in chemical mixers, coolant flow, etc. *Eastman Kodak Co.*

299. Carbon Control
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup Co.*

300. Castings
Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

301. Cleaning and Buffing
Bulletin 44 contains an interesting discussion of barrel deburring, as well as methods of removing many kinds of burrs from sawing, drilling, milling and stamping operations. *Magnus Chemical Co.*

302. Cleaning Brushes
New booklet shows 12 actual case histories of how they provide thorough cleaning of welds, stainless sheet, hot cast iron, automotive parts, brass fixtures, and others. *Pittsburgh Plate Glass Co., Brush Div.*

303. Coatings, Metal
Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal Coatings by High Vacuum". *Distillation Products, Inc.*

304. Coatings, Zinc
16-page illustrated booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. *St. Joseph Lead Co.*

305. Cold Drawing
Full information available on complete drawing service — cleaners, rinses, Bonderite, and lubricants to solve all cold drawing and cold extrusion problems. *Parker Rust Proof Co.*

306. Combustion Control
32-page catalog 9601 provides a complete manual on flame failure protection for industrial applications. Includes information on new "flame-rectification principle" with installation drawings and comprehensive data on 24 different safeguard systems. *Minneapolis-Honeywell Regulator Co., Industrial Div.*

307. Copper Alloy Tubes
An extensively illustrated 32-page brochure, "Life Extension for Condenser Tubes", deals with causes of corrosion and means of combating them, as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

308. Copper and Copper Alloys
New 24-page booklet B-36 discusses corrosive attack on copper and copper alloys. Includes tabulation for relative corrosion resistance of principal types of copper-base alloys. *American Brass Co.*

309. Cutting Oils
New bulletin on "Gulf Electro Cutting Oil", which contains larger percentage of active sulphur ingredient, recommended for toughest machining jobs. *Gulf Oil Corp.*

310. Cutting Oils
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service Oil Co.*

311. Cutting Oils
Send for your copy of Stuart's Shop Notebook, giving important facts on right cutting fluid for any machining operation. *D. A. Stuart Oil Co.*

312. Cutting Oils
Factual data on more than fifty typical metal-working jobs are presented in new 80-page edition of "Cutting and Grinding Facts". Also includes descriptions of straight and emulsifiable cutting oils with convenient chart for correct use. *Sun Oil Co.*

313. Dry Cooler
Bulletin DC-50 illustrates complete line of DriCoolers in a wide range of capacities and designs for specific cooling jobs. *Marley Co.*

314. Ductile Cast Iron
New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. *International Nickel Co.*

315. Electrodes, Hard-Facing
Bulletin announcing completely new line of Wear-Arc hard-facing alloy electrodes. Includes full data on typical applications with physical properties, welding procedure and identification. *Alloy Rods Co.*

316. Electron Microscope
The new table model RCA electron microscope is described and illustrated in a 12-page booklet. *Radio Corp. of America.*

317. Finishes
New 4-page two-color bulletin describes in detail the entire line of Iridite finishes for nonferrous metals. Also includes section on ARP process chemicals such as bright hardeners for zinc and cadmium plating and other specialties. *Allied Research Products, Inc.*

318. Forgings
New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. *Merrill Bros. Co.*

319. Forgings
Technical bulletin 31 furnishes helpful information on stainless forging problems and includes specific data on chemical composition of alloy steels. *Timken Roller Bearing Co.*

320. Furnace
Full information furnished on new gas-at phere high-production furnace for handling b annealing of wire, strip and bar stock of copper nonferrous copper alloys. *Holcroft & Co.*

321. Furnace, Atmosphere
Bulletin F-1 gives full description of vers controlled-atmosphere furnace for all steels high carbon to high speed in range 1200-280 *Delaware Tool Steel Corp.*

322. Furnaces
High temperature furnaces for temperature to 2000°F are described in leaflet. *Carl-M Corp.*

323. Furnaces
New bulletin 84P describes eight sizes in g electric models as well as conveyorized and b or pot-type furnaces. *Despatch Oven Co.*

324. Furnaces
Descriptive bulletins on salt pot furnaces wide range of sizes for either high or low-pre gas in heat treating small parts with lead, cya or other salt bath processes. *Eclipse Fuel E neering Co.*

325. Furnaces
Complete "Buzzer" catalog available descri Buzzer high-speed gas furnaces designed prim for heat treating high carbon and alloy steels also atmospheric pot hardening furnaces for cyanide and lead hardening. *Charles A. Hones,*

326. Furnaces, Industrial
6-page folder describes 18 typical installat of gas-fired and electric furnaces of various ty complete with specially designed equipment bright annealing, scale-free hardening, carbon toration, carburizing and production heat t ment. *Electric Furnace Co.*

327. Gas Analyzer
Further information available on Type 09-1 a new packaged unit vacuum fusion gas anal used to determine the content of oxygen, nitr and hydrogen in metals. *National Research C*

328. Hardness Tester, Porta
Illustrated circular describing the Ames port hardness tester in sizes for work 1 inch to 6 in round and flat. *Ames Precision Machine W*

329. Heating Elements, Electric
Bulletin H gives detailed information on AT- nonmetallic electric heating elements, inclu tables for a wide variety of sizes available. *Gl Div., Carborundum Co.*

330. Heat Treating
Barrett standard anhydrous ammonia is a able in 150, 100 and 50-pound cylinders in veniently located stock points. Send for literat *Barrett Div., Allied Chemical & Dye Corp.*

331. Heat Treating
Ipsenlab periodic sheets show case historie bright hardening, annealing and carburizing. *I Industries, Inc.*

332. Heat Treating
Bulletin 96 tells how Niagara Aero heat changers provide better heat treating by evapor cooling that controls temperatures, protects pl cal properties, and saves on water and p equipment. *Niagara Blower Co.*

333. Heat Treating Carriers
Complete line of standard carburizing car that will handle odd-shaped parts of every through carburizing and quenching to finish Write for full information. *Pressed Steel Co.*

334. Heat Treating Equipme
Bulletin 820 gives detailed description complete specifications on various size autom quenching tanks for use with continuous treating equipment. *American Gas Furnace*

335. Heat Treating Furnaces
Illustrated literature describes newest deve ments in gas and electric heat treating furn *Westinghouse Electric Corp.*

336. Heat Treating Pots
New bulletin T-205 lists 118 patterns avail in Thermalloy heat treating pots, both round rectangular, X-rayed and pressure tested for sc and economical service. *Electro-Alloys Div.*

337. High Speed Steel
Full information on performance, heat t ment and other authoritative facts furnishe booklet entitled "Molybdenum High Speed Ste *Climax Molybdenum Co.*

338. Immersion Heating
Bulletin IE-11 gives complete details on new immersion pots save time and money melting soft metals. High thermal efficiency both large and small units provides rapid recovery in one-third the time. *C. M. K Mfg. Co.*

339. Induction Heating
Bulletin 1440 furnishes full details on "Checklite" system for safety control through use of oversized components built into every for longer service life and uninterrupted product *Lindberg Engineering Co.*

What's New

IN MANUFACT

320. Furnace
Full information furnished on new gas-atmosphere high-production furnace for handling bright annealing of wire, strip and bar stock of copper and nonferrous copper alloys. *Holcroft & Co.*

321. Furnace, Atmosphere
Bulletin F-1 gives full description of versatile, controlled-atmosphere furnace for all steels from high carbon to high speed in range 1200–2800°F. *Delaware Tool Steel Corp.*

322. Furnaces
High temperature furnaces for temperatures up to 2000°F are described in leaflet. *Carl-Mayer Corp.*

323. Furnaces
New bulletin 84P describes eight sizes in gas or electric models as well as conveyorized and batch or pot-type furnaces. *Despatch Oven Co.*

324. Furnaces
Descriptive bulletins on salt pot furnaces in a wide range of sizes for either high or low-pressure gas in heat treating small parts with lead, cyanide or other salt bath processes. *Eclipse Fuel Engineering Co.*

325. Furnaces
Complete "Buzzer" catalog available describing Buzzer high-speed gas furnaces designed primarily for heat treating high carbon and alloy steels and also atmospheric pot hardening furnaces for salt, cyanide and lead hardening. *Charles A. Hones, Inc.*

326. Furnaces, Industrial
6-page folder describes 18 typical installations of gas-fired and electric furnaces of various types, complete with specially designed equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

327. Gas Analyzer
Further information available on Type 09-1240, a new packaged unit vacuum fusion gas analyzer, used to determine the content of oxygen, nitrogen and hydrogen in metals. *National Research Corp.*

328. Hardness Tester, Portable
Illustrated circular describing the Ames portable hardness tester in sizes for work 1 inch to 6 inches round and flat. *Ames Precision Machine Works.*

329. Heating Elements, Electric
Bulletin H gives detailed information on AT-type nonmetallic electric heating elements, including tables for a wide variety of sizes available. *Globar Div., Carborundum Co.*

330. Heat Treating
Barrett standard anhydrous ammonia is available in 150, 100 and 50-pound cylinders in conveniently located stock points. Send for literature. *Barrett Div., Allied Chemical & Dye Corp.*

331. Heat Treating
Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. *Ipsen Industries, Inc.*

332. Heat Treating
Bulletin 96 tells how Niagara Aero heat exchangers provide better heat treating by evaporated cooling that controls temperatures, protects physical properties, and saves on water and piping equipment. *Niagara Blower Co.*

333. Heat Treating Carriers
Complete line of standard carburizing carriers that will handle odd-shaped parts of every type through carburizing and quenching to finishing. Write for full information. *Pressed Steel Co.*

334. Heat Treating Equipment
Bulletin 820 gives detailed description with complete specifications on various size automatic quenching tanks for use with continuous heat treating equipment. *American Gas Furnace Co.*

335. Heat Treating Furnaces
Illustrated literature describes newest developments in gas and electric heat treating furnaces *Westinghouse Electric Corp.*

336. Heat Treating Pots
New bulletin T-205 lists 118 patterns available in Thermalloy heat treating pots, both round and rectangular, X-rayed and pressure tested for sound and economical service. *Electro-Alloys Div.*

337. High Speed Steel
Full information on performance, heat treatment and other authoritative facts furnished in booklet entitled "Molybdenum High Speed Steels". *Climax Molybdenum Co.*

338. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

339. Induction Heating
Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

340. Induction Heating
For more economical manufacture in designing and redesigning present products, send for copy of "Design and Manufacture for Profit" with full details on Tocco Induction Heating for brazing, hardening, soldering, forging or shrink-fitting. *Ohio Crankshaft Co.*

341. Industrial Planning
New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

342. Industrial X-Ray
New catalog on "Industrial X-Ray Accessories" provides complete listing of this equipment, including chemicals, dark-room accessories, filing equipment, processing tanks, dryers and radiation instruments. *Picker X-Ray Corp.*

343. Insulation, Block
New 4-page folder on Superex block insulation tells economical advantages and lists outstanding properties by means of conductivity and heat loss graphs and recommended thickness table. *Johns-Manville.*

344. Iron, High Chromium
New booklet, "Abrasion-Resistant High-Chromium Iron", furnishes a complete file of the best available information on how to make and use abrasion-resistant iron castings most efficiently. *Electro Metallurgical Co.*

345. Lab Furnaces
New pot furnaces for laboratory and research use are described in bulletins HD-635 and HD-546. *Hevi Duty Electric Co.*

346. Laboratory Equipment
New literature ready on complete line of rapid carbon analyzers for steel, cast iron, pig iron, coal, coke, oil and cracking catalyst. *Laboratory Equipment Corp.*

347. Laboratory Safety
Newly revised edition of 40-page booklet includes recently developed data, techniques and equipment, and provides useful manual for setting up complete laboratory safety programs. *Fisher Scientific Co.*

348. Load Testing
Bulletin 325 describes new Type P SR-4 tension load cells based on SR-4 bonded resistance wire strain gages for load measurement. Gives specifications for load cells of four capacities between 10,000 and 100,000 pounds. *Baldwin-Lima-Hamilton Corp.*

349. Load Testing
Brochure 501 gives full details on universal testing machines in three ranges: Model TMU-A, 0–30,000, 0–6000, 0–600 lbs.; Model TMU-B, 0–15,000, 0–3000, 0–300 lbs. *National Forge & Ordnance Co.*

• If mailed from countries ou
amount of postage stamps m

BUSINESS REP
No Postage Stamp Necessary If Maile

4¢ POSTAGE WILL B

METAL PRO
7301
CL

FACTURERS' LITERATURE

350. Low-Melting Alloy
20-page manual on use of low-melting alloy in punch and die setting. Profusely illustrated. *Cerro dePasco Corp.*

351. Magnesium Die Castings
Revealing book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co*

352. Melting, Induction
8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

353. Metal Analysis
Bulletin 220-F describes completely new mercury cathode, Dyna-Cath, that provides economical and high-speed separation of iron in determination of aluminum in steel. *Eberbach Corp.*

354. Metal Cleaning
Information on new cleaning process that uses emulsion cleaners, based on petroleum and addition agent 230. This two-phase bath provides unique cleaning in conjunction with a thin displacement film that removes foreign particles. *Northwest Chemical Co.*

355. Metal Cleaning
New 44-page booklet, "Some Good Things to Know About Metal Cleaning", discusses wide variety of soils resulting from such metal-fabricating jobs as heat-treating, forging, rolling, stamping, drawing, extruding, spinning, grinding, machining, buffing, etc., and describes specific materials, equipment and procedures for their removal. *Oakite Products, Inc.*

356. Metal Coating
Bulletin entitled "How To Obtain A Grade I Finish On Steel" furnishes full details on special protective coating required by Government Specification JAN-C-490. *American Chemical Paint Co.*

357. Metal Finishing
New check list available on sixty products and processes for metal finishing, including a new acid addition agent, a cleaning and pickling agent combined, new complete inhibitor and a new rust preventive compound. *Enthone, Inc.*

358. Metal-Forming Lubrication
New bulletin 426-B describes how colloidal graphite can solve your lubrication problems in metal-forming operations at temperatures from below zero up to 5000°F. *Acheson Colloids Corp.*

359. Metal Hydrides
4-page folder on various hydrides of metals. Describes the use of these compounds in alloying, powder metallurgy and other metallurgical and chemical applications. *Metal Hydrides, Inc.*

es outside the United States, proper
os must be affixed for returning card

FIRST CLASS
PERMIT No. 1595
(Sec. 34.9 P.L. & R.)
Cleveland, Ohio

EPLY CARD
Mailed in the United States

L BE PAID BY—

ROGRESS
001 Euclid Avenue
CLEVELAND 3, OHIO

What's New

IN MANUFA

360. Metalworking Data File
Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

361. Micrographic Equipment
Six-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000 X. Full details on optics and accessories included. *Opplem Co.*

362. Microscopes
Well-illustrated 22-page booklet on Dynoptic Labroscopes, featuring ball bearings and rollers throughout the focusing system as well as low position fine adjustment with low controls that enable the operator to manipulate other controls more easily. *Bausch & Lomb Optical Co.*

363. Midget Die Casting Machine
Illustrated folder describes new Kux Model K, small die casting machine, available in horizontal or vertical center shot models and capable of producing die castings weighing up to 1½ pounds in zinc under high injection pressures. *Kux Machine Co.*

364. Nickel Silver
Paper dealing with detailed description of proper foundry procedure for production of sound castings from nickel silver. Also specification information. *R. Lavin & Sons, Inc.*

365. Oil Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

366. Organic Solvents
64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common use. Pocket-size for easy reference. *Solvents & Chemicals Group.*

367. Photomicrography
Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

368. Plating Barrels
4-page folder illustrates and describes the Daniels Plating Barrel designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply Co.*

369. Plating Generators
Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

• If mailed from countries outside
amount of postage stamps must b

METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

September, 1951

268	291	314	337	360	383
269	292	315	338	361	384
270	293	316	339	362	385
271	294	317	340	363	386
272	295	318	341	364	387
273	296	319	342	365	388
274	297	320	343	366	389
275	298	321	344	367	390
276	299	322	345	368	391
277	300	323	346	369	392
278	301	324	347	370	393
279	302	325	348	371	394
280	303	326	349	372	395
281	304	327	350	373	396
282	305	328	351	374	397
283	306	329	352	375	398
284	307	330	353	376	399
285	308	331	354	377	400
286	309	332	355	378	
287	310	333	356	379	
288	311	334	357	380	
289	312	335	358	381	
290	313	336	359	382	

Please have litera

Name

Company

Products Manufa

Address

City and State

Postcard must be
Students

UFACTURERS' LITERATURE

370. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. *Acme Mfg. Co.*

371. Pyrometer
Catalog No. 165 describes improved Pyro surface pyrometer. Eight instruments in one, it handles all surface and sub-surface temperature measuring jobs. *Pyrometer Instrument Co.*

372. Pyrometer
New, general-purpose, low-temperature model, portable pyrometer now available as Type LT-840 Xactemp in a choice of four calibrations. *Claud S. Gordon Co.*

373. Quenching
For full information on the newest developments of Ajax isothermal heat treat process in martempering, austempering and other interrupted quenching operations, send for bulletin 120. *Ajax Electric Co.*

374. Quenching Oil
New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

375. Quench-Oil Cooler
10-page bulletin tells how cooling and circulation of quench oils assures control and saves time by continuous operation, in addition to reducing oil losses and fire hazards. Includes selection, capacity and dimension data. *The Trane Co.*

376. Reclaiming Process
Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. *Chas. Engelhard, Inc.*

377. Recording Meters
New 28-page bulletin E-1111 describes Series 500 recording voltmeters and ammeters with special emphasis on newly-developed moving-iron measuring mechanism. Complete data on ranges, and specifications of various models for permanent and portable use. *Bristol Co.*

378. Refractories
40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. *Carborundum Co.*

379. Refractory
Form 1409 describes the new Norton Fused Stabilized Zirconia, ideal refractory for furnace linings, metal melting, thermal insulation, Batts for firing Titanates and electric heater elements. *Norton Co.*

380. Refractory Mixes
Well-illustrated 16-page bulletin No. 315 provides important data on properties and applications of Sillimanite Super-Refractory ramming mixes and patches. *Chas. Taylor Sons Co.*

tside the United States, proper ust be affixed for returning card

e literature circled at the left sent to me.

Title

Manufactured

tate

ust be mailed prior to December 1, 1951—
dents should write direct to manufacturers.

381. Rust Preventive
New "How" book shows how slushing and degreasing problems can be eliminated by Vapor-Wrapper method of packaging machines and parts. *Nox-Rust Chemical Corp*

382. Salt Baths
Valuable technical information available on heat treatment and molten salt bath operations. *E. I. duPont de Nemours & Co.*

383. Soaking Pit
4-page technical bulletin with details on the construction and performance of new soaking pit which will reduce fuel consumption by 40% while almost doubling amount of steel heated. *Loftus Engineering Corp.*

384. Solder
36-page educational brochure on the properties and applications of solder. Profusely illustrated, with a resume of technical data and solder specifications of ASTM, SAE, Federal and Military agencies. *American Smelting & Refining Co.*

385. Specimen Mount Press
New bulletin describing AB Speed Press. Features include use of preheated premolds, rapid closing and universal application for thermosetting or thermoplastic materials in 3 sizes. *Buehler Ltd.*

386. Spring Wire
Detailed information on Pittsburgh ol tempered spring wire to help solve coiling, knotting, forming and twisting operation problems. *Pittsburgh Steel Co.*

387. Steel, Brake Die
For full information on top quality brake die steel, engineered to machine easily and give long service, write for folder 560. *Bethlehem Steel Co.*

388. Steels, Low Alloy
You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. *Inland Steel Co.*

389. Steels, Low-Alloy
Well-illustrated, 8-page folder on N-A-X low-alloy steels lists physical properties and test specifications. *Great Lakes Steel Corp.*

390. Steels, Stainless
Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

391. Stud Welding Manual
New 32-page pocket-size Stud Welding Operating Manual available with step-by-step photographic explanation of actual stud welding process. *K S M Products, Inc.*

392. Testing
New 30-page catalog on screw power universal testing machines and accessories includes illustrations and details of construction and specifications. Also information on special tools for different tests. *American Machine & Metals, Inc.*

393. Testing Machine
Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. *Tinius Olsen Testing Machine Co.*

394. Tool and Lab Furnace
New literature on hardening and tempering furnace designed to give automatic control of the entire temperature range from 300 to 2200°F. *K. H. Huppert Co.*

395. Tool Steel
New booklet, "How to Get Better Tool and Die Performance", furnishes full description of the matched set method for selecting the right tool steel for trouble-free production. *Carpenter Steel Co.*

396. Tubes, Bars, Steel
New stock list now available on 52100 tubing and bars as well as ring forgings. *Peterson Steels, Inc.*

397. Tubing
For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of Seamless and Weldrawn tubing, send for bulletin 32. *Superior Tube Co.*

398. Vapor Degreasing
Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

399. Wear-Resistant Castings
New descriptive folder gives interesting facts on Colmonoy hard facing alloys, developed to combat different types of wear: abrasion, corrosion, impact, etc. Made in various forms to suit the methods of application. *Wall Colmonoy Corp.*

400. Welding, Oxy-Acetylene
16-page illustrated booklet traces the history of oxy-acetylene flame and explains how industry is using it today in cutting, welding, and heating operations. Many specialized jobs briefly described, such as hard-facing, flame-softening, flame-hardening, powder-cutting and steel-conditioning. *Linde Air Products Co.*

What's New

IN MANUFACTURERS' LITERATURE

360. Metalworking Data File
Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

361. Micrographic Equipment
Six-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000 ×. Full details on optics and accessories included. *Opplem Co.*

362. Microscopes
Well-illustrated 22-page booklet on Dynoptic Labroscopes, featuring ball bearings and rollers throughout the focusing system as well as low position fine adjustment with low controls that enable the operator to manipulate other controls more easily. *Bausch & Lomb Optical Co.*

363. Midget Die Casting Machine
Illustrated folder describes new Kux Model K, small die casting machine, available in horizontal or vertical center shot models and capable of producing die castings weighing up to 1½ pounds in zinc under high injection pressures. *Kux Machine Co.*

364. Nickel Silver
Paper dealing with detailed description of proper foundry procedure for production of sound castings from nickel silver. Also specification information. *R. Lavin & Sons, Inc.*

365. Oil Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

366. Organic Solvents
64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common use. Pocket-size for easy reference. *Solvents & Chemicals Group.*

367. Photomicrography
Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

368. Plating Barrels
4-page folder illustrates and describes the Daniels Plating Barrel designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply Co.*

369. Plating Generators
Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

370. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. *Acme Mfg. Co.*

371. Pyrometer
Catalog No. 165 describes improved Pyro surface pyrometer. Eight instruments in one, it handles all surface and sub-surface temperature measuring jobs. *Pyrometer Instrument Co.*

372. Pyrometer
New, general-purpose, low-temperature model, portable pyrometer now available as Type LT-840 Xactemp in a choice of four calibrations. *Claud S. Gordon Co.*

373. Quenching
For full information on the newest developments of Ajax isothermal heat treat process in martempering, austempering and other interrupted quenching operations, send for bulletin 120. *Ajax Electric Co.*

374. Quenching Oil
New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

375. Quench-Oil Cooler
10-page bulletin tells how cooling and circulation of quench oils assures control and saves time by continuous operation, in addition to reducing oil losses and fire hazards. Includes selection, capacity and dimension data. *The Trane Co.*

376. Reclaiming Process
Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. *Chas. Engelhard, Inc.*

377. Recording Meters
New 28-page bulletin E-1111 describes Series 500 recording voltmeters and ammeters with special emphasis on newly-developed moving-iron measuring mechanism. Complete data on ranges, and specifications of various models for permanent and portable use. *Bristol Co.*

378. Refractories
40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. *Carborundum Co.*

379. Refractory
Form 1409 describes the new Norton Fused Stabilized Zirconia, ideal refractory for furnace linings, metal melting, thermal insulation, Batts for firing Titanates and electric heater elements. *Norton Co.*

380. Refractory Mixes
Well-illustrated 16-page bulletin No. 315 provides important data on properties and applications of Sillimanite Super-Refractory ramming mixes and patches. *Chas. Taylor Sons Co.*

381. Rust Preventive
New "How" book shows how slushing and degreasing problems can be eliminated by Vapor-Wrapper method of packaging machines and parts. *Nox-Rust Chemical Corp*

382. Salt Baths
Valuable technical information available on heat treatment and molten salt bath operations. *E. I. duPont de Nemours & Co.*

383. Soaking Pit
4-page technical bulletin with details on the onstruction and performance of new soaking pit which will reduce fuel consumption by 40% while almost doubling amount of steel heated. *Loftus Engineering Corp.*

384. Solder
36-page educational brochure on the properties and applications of solder. Profusely illustrated, with a resume of technical data and solder specifications of ASTM, SAE, Federal and Military agencies. *American Smelting & Refining Co.*

385. Specimen Mount Press
New bulletin describing AB Speed Press. Features include use of preheated premolds, rapid closing and universal application for thermosetting or thermoplastic materials in 3 sizes. *Buehler Ltd.*

386. Spring Wire
Detailed information on Pittsburgh oi tempered spring wire to help solve coiling, knotting, forming and twisting operation problems. *Pittsburgh Steel Co.*

387. Steel, Brake Die
For full information on top quality brake die steel, engineered to machine easily and give long service, write for folder 560. *Bethlehem Steel Co.*

388. Steels, Low Alloy
You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. *Inland Steel Co.*

389. Steels, Low-Alloy
Well-illustrated, 8-page folder on N-A-X low-alloy steels lists physical properties and test specifications. *Great Lakes Steel Corp.*

390. Steels, Stainless
Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

391. Stud Welding Manual
New 32-page pocket-size Stud Welding Operating Manual available with step-by-step photographic explanation of actual stud welding process. *K S M Products, Inc.*

392. Testing
New 30-page catalog on screw power universal testing machines and accessories includes illustrations and details of construction and specifications. Also information on special tools for different tests. *American Machine & Metals, Inc.*

393. Testing Machine
Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. *Tinius Olsen Testing Machine Co.*

394. Tool and Lab Furnace
New literature on hardening and tempering furnace designed to give automatic control of the entire temperature range from 300 to 2200°F. *K. H. Huppert Co.*

395. Tool Steel
New booklet, "How to Get Better Tool and Die Performance", furnishes full description of the matched set method for selecting the right tool steel for trouble-free production. *Carpenter Steel Co.*

396. Tubes, Bars, Steel
New stock list now available on 52100 tubing and bars as well as ring forgings. *Peterson Steels, Inc.*

397. Tubing
For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of Seamless and Weldrawn tubing, send for bulletin 32. *Superior Tube Co.*

398. Vapor Degreasing
Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

399. Wear-Resistant Castings
New descriptive folder gives interesting facts on Colmonoy hard facing alloys, developed to combat different types of wear: abrasion, corrosion, impact, etc. Made in various forms to suit the methods of application. *Wall Colmonoy Corp.*

400. Welding, Oxy-Acetylene
16-page illustrated booklet traces the history of oxy-acetylene flame and explains how industry is using it today in cutting, welding, and heating operations. Many specialized jobs briefly described, such as hard-facing, flame-softening, flame-hardening, powder-cutting and steel-conditioning. *Linde Air Products Co.*

[• If mailed from countries outside the United States, proper amount of postage stamps must be affixed for returning card]

METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

September, 1951

268	291	314	337	360	383
269	292	315	338	361	384
270	293	316	339	362	385
271	294	317	340	363	386
272	295	318	341	364	387
273	296	319	342	365	388
274	297	320	343	366	389
275	298	321	344	367	390
276	299	322	345	368	391
277	300	323	346	369	392
278	301	324	347	370	393
279	302	325	348	371	394
280	303	326	349	372	395
281	304	327	350	373	396
282	305	328	351	374	397
283	306	329	352	375	398
284	307	330	353	376	399
285	308	331	354	377	400
286	309	332	355	378	
287	310	333	356	379	
288	311	334	357	380	
289	312	335	358	381	
290	313	336	359	382	

Please have literature circled at the left sent to me.

Name ______________________ Title ______________

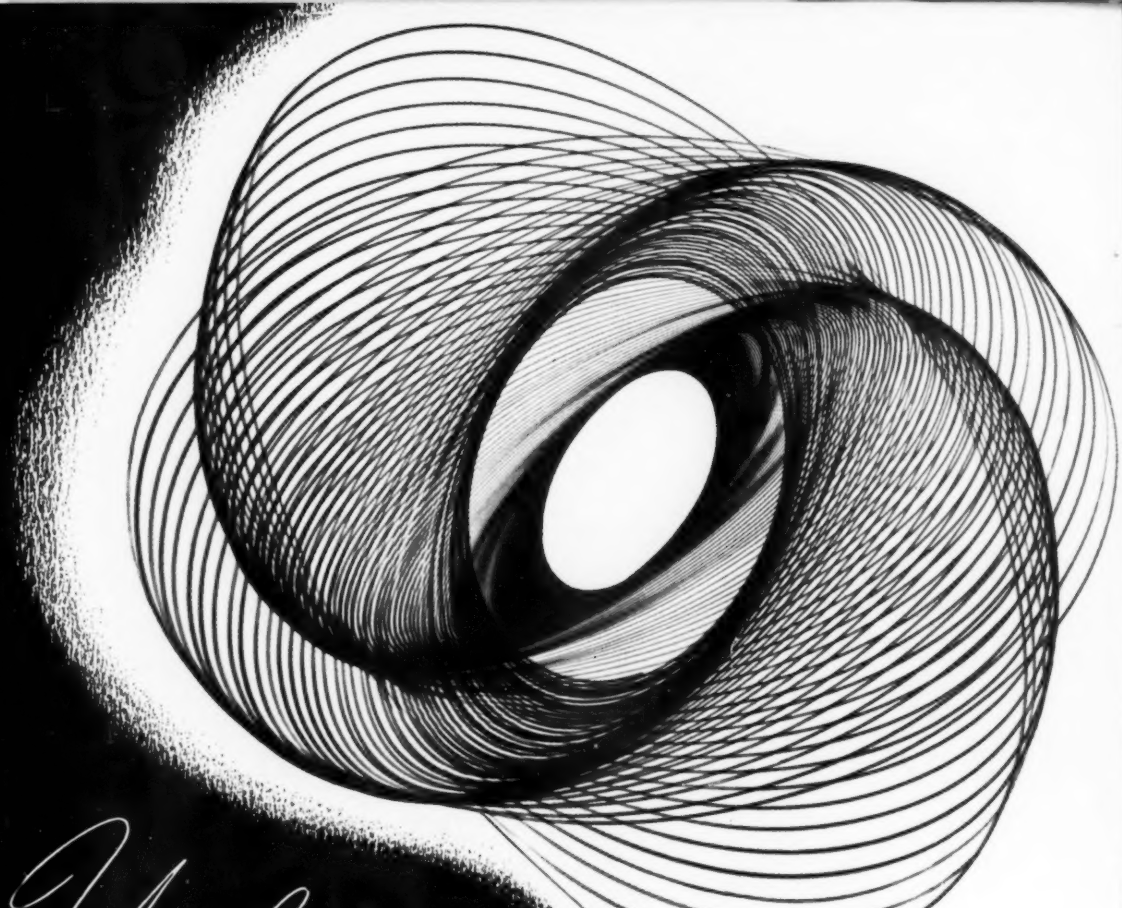
Company ______________________

Products Manufactured ______________________

Address ______________________

City and State ______________________

**Postcard must be mailed prior to December 1, 1951—
Students should write direct to manufacturers.**


Uniform

New Development in Salt Baths

Eliminates scale and decarburization on steels in neutral salt baths operating up to 2300° F.

NEUTRAL hardening in molten salt baths should mean just what it says. No scale or decarburization is present in a properly rectified neutral salt, regardless of temperatures used. This is possible at 1500°F. and up to 2300°F. A recent development by one of the leading salt bath suppliers makes this possible for the first time without the manual addition of solid deoxidizers. The Neutra-Gas Process (U. S. Patent No. 2474680) is simple, effective, and inexpensive. Merely bubble an inexpensive commercial gas through the molten bath for recommended periods. Neutrality is easily checked chemically or physically. The Neutra-Gas Process is operating at the present time in molten baths weighing less than 100 pounds and those holding several tons of salt.

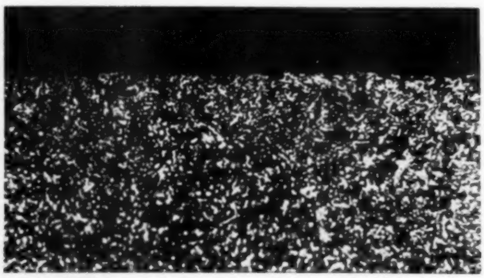
A truly neutral salt is the ideal medium for heating all steels with no surface effect. There is no atmosphere, and air is excluded while the work is heating. Scaling and decarburization are prevented. A thin film of salt protects parts right up to the quench. With neutral salts operating at 1500°-1600°F., Neutra-Gas is used for just a few minutes per shift. Sludging is practically eliminated; economies result because sludging removes good usable salt. The bath remains very fluid allowing rapid and uniform heating with less distortion. To obtain all the advantages of salt bath hardening, use salt baths for both heating and quenching The improved fluidity of the Neutra-Gas controlled neutral salt assists materially in isothermal quenching salt operations.

Neutral Salts from 850° — 1850°

Various salt mixtures provide a wide range of usefulness in the heat treatment of steel. The Neutra-Gas is used with chloride mixtures only. The most popular type is Park Nu-Sal Neutral Salt. Its melting point is 1230°F. with a range of 1300°-1600°F. Most steel hardening temperatures fall within this range. Nu-Sal is widely used as the austenizing bath for isothermal treatments such as austempering and martempering.

Cycle annealing involves a wider range of temperatures. Park K-3 Neutral Salt melts at 1020°F. and is usable past 1700°; periodic use up to 1850° is permitted if proper rectification is made with Neutra-Gas.

Low melting salts are available for special purposes. Park's #800 Neutral Salt (melting point 850°F.) and Park #900 Salt (melting point 920°) are used for tempering, high speed steel quenching, and have a range up to 1700°F.



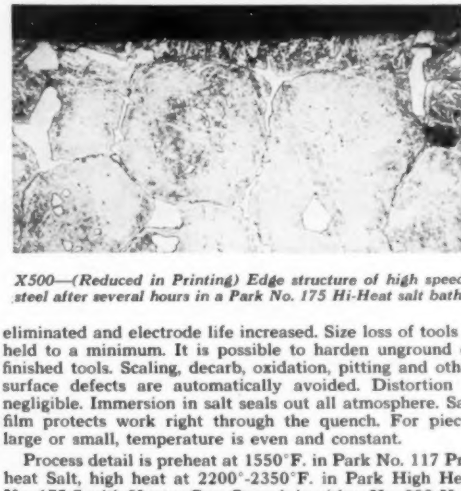
(X 500) Microphotograph of the edge structure on SAE 1095 steel treated for 60 minutes at 1450°F. in a commercial installation of Park Nu-Sal kept neutral with the Neutra-Gas process. (Sample quenched in caustic solution and tempered in No. 800 Neutral Salt at 1200°F.)

Baths operating consistently at 1700° to 1900°F. usually operate with less fuming and volatilization if their melting points and top operating temperatures are slightly higher. Park K-17, with a range up to 1900°F., also has a reasonably low melting point of 1175°F. Economy is indicated here as the temperature of an idle furnace may be kept at 1250°-1300° with very low power costs.

No Decarb on Moly High Speed Steels

Wider use of molybdenum high speed tool steels has virtually made the use of salt baths mandatory. During the last War it was salt baths which made possible the adoption of the molybdenum high speed steels in place of the very critical tungsten types.

As in most instances, the increased use of a method leads to rapid improvements. The improved rectification of high heat salt baths operating from 2200°-2300°F. is a development of the Park Chemical Company laboratories. The Neutra-Gas Process was adapted to the higher temperature applications in order to reduce the oxides of the chloride salts. Metallic oxides are reduced by graphite rods immersed in the salt. Costly and laborious sludging has been nearly

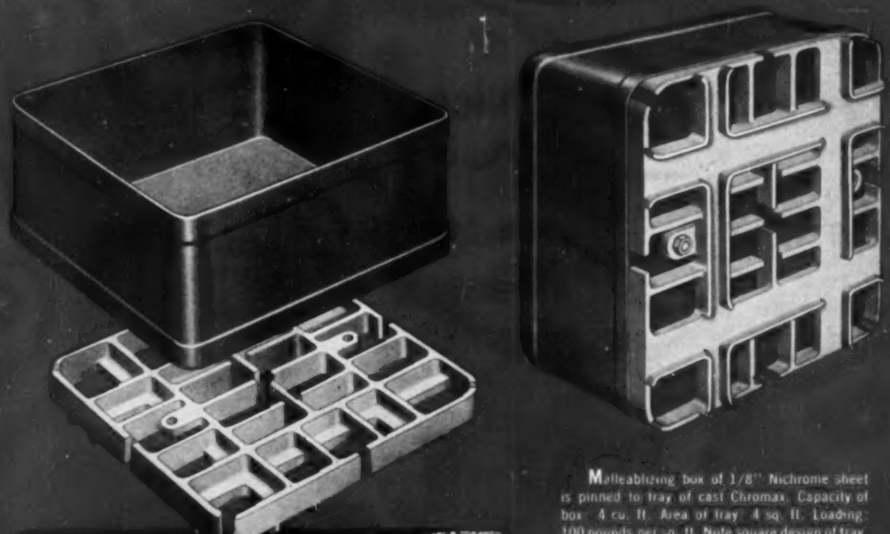


X500—(Reduced in Printing) Edge structure of high speed steel after several hours in a Park No. 175 Hi-Heat salt bath.

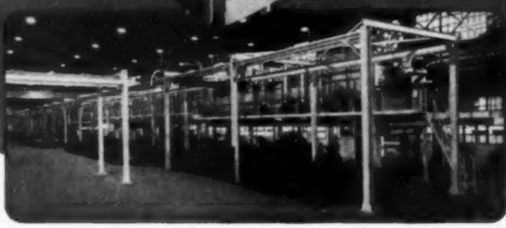
eliminated and electrode life increased. Size loss of tools is held to a minimum. It is possible to harden unground or finished tools. Scaling, decarb, oxidation, pitting and other surface defects are automatically avoided. Distortion is negligible. Immersion in salt seals out all atmosphere. Salt film protects work right through the quench. For pieces large or small, temperature is even and constant.

Process detail is preheat at 1550°F. in Park No. 117 Preheat Salt, high heat at 2200°-2350°F. in Park High Heat No. 175-S with Neutra-Gas. Quench in either No. 900 Neutral Salt, or in No. 100 Quench Salt which contains a small amount of cyanide. Tempering in salt completes the cycle, free from any deleterious effect caused by contact with the atmosphere.

Park's salt baths, and the knowledge of how to make them do a better job for you, can effect economies in your heat treat department. Write, telling us in detail your application, and we will send you the technical bulletin that covers your particular operation. There is a Park field engineer to assist you, backed by a technical staff and 40 years of Park Chemical Co. service to the heat treating industry. Park Chemical Company, 8074 Military Ave., Detroit 4, Michigan.



Malleablizing box of 1/8" Nichrome sheet is pinned to tray of cast Chromax. Capacity of box: 4 cu. ft. Area of tray: 4 sq. ft. Loading: 100 pounds per sq. ft. Note square design of tray, permitting it to be turned 90° to maintain dimensions in pusher-type furnace, and operated easily on conveyor systems connecting at 90° angle.



One of many Holcroft malleablizing furnaces in which the above type of equipment is used.

How Live Load Ratio was improved 250%

A large midwestern implement foundry has proved that use of trays and boxes made of Driver-Harris alloys, for malleable annealing of small parts, results in outstanding savings in deadweight and better heat transfer. Production has been stepped up considerably by increasing live load and shortening the heat-treating cycle.

Hard cast iron boxes, formerly used in tunnel kilns, weighed 650 pounds each, and carried a maximum work load of 330 pounds—giving a load ratio of approximately 0.5 to 1.

Boxes in service today are fabricated from 1/8" Nichrome* sheet. These are pinned to specially designed trays of cast Chromax* (see illustration). Box load is 400 pounds. Total weight of a box and tray is 180 pounds. Thus load ratio is 400 to 180, or approximately 2¼ to 1.

Such a remarkable improvement in the ratio of live load to deadweight of containers (almost 250%) has, of course, resulted in proportionate improvement in efficiency—or fuel saving.

To date, these boxes and trays have given 36 months of service in a continuous malleablizing furnace. During this period, they have made 480 trips through the furnace—representing 480 heat and cool cycles. They have been in the furnace 22,640 hours, about 86% of the total elapsed time, under temperatures up to 1725°F. Each box has annealed 90 tons of work.

Neither boxes nor trays are showing any permanent distortion or embrittlement. In fact, they are performing as well today as when first put into service, and are proving conclusively that malleable annealing can be a clean, labor-saving, fuel-saving operation.

Here is but another example of how Driver-Harris alloys are being applied to great advantage in the heat-treating field. Why not consult with us for a solution to *your* heat-treating equipment and furnace part problems? Although the demand for D-H products in the present emergency is engaging the resources of this firm to an unprecedented extent, we shall be glad to serve you to the best of our ability.

Nichrome and Chromax are manufactured only by

Driver-Harris Company

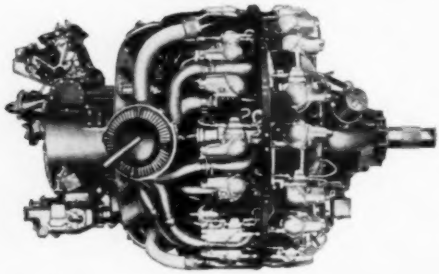
HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T. M. Reg. U. S. Pat. Off.

Enduro®

HELPS HARNESS THE "CYCLONE"



• Each new Wright 18-compound "Turbo-Cyclone" aircraft engine puts 3250 horsepower roaring into action. Helping convert that tremendous power into flashing aircraft performance is this turbine shaft, precisely machined from ENDURO Stainless Steel.

ENDURO serves the aircraft power plant designer and producer well. Free-machining ENDURO bars—both hot rolled and cold drawn—economically pair exceptional resistance to heat, abrasion and corrosion with great strength and durability.

ENDURO responds readily to forging. As this shaft indicates, it is readily machinable. Two ENDURO grades, for example, are fully 90% as machinable as Bessemer screw stock. In cold finished bar form, ENDURO provides close tolerances, accuracy of section, uniform soundness, and fine surface finish.

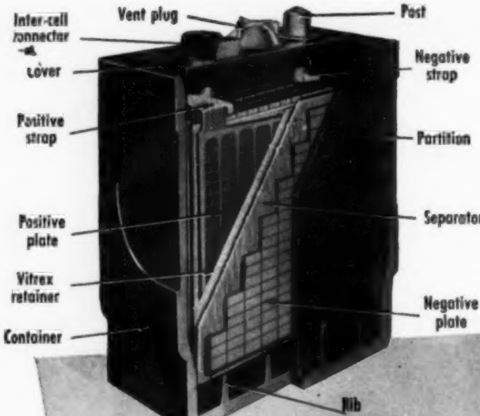
Need help in harnessing too-high machining costs in your own stainless steel parts? The combination of free-machining ENDURO and competent Republic metallurgical help has held costs down for many a manufacturer. Write:

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.

Republic ENDURO® FREE-MACHINING STAINLESS STEEL

REPUBLIC STEEL

Other Republic Products include Carbon and Alloy Steels—Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing



One cell of a 3-cell 6-volt automobile battery cut away to show construction.

$$PbO_2 + Pb + 2H_2SO_4 \rightleftarrows 2PbSO_4 + 2H_2O$$

this electrochemical reaction accounts for the *largest use of lead!*

The operation of the modern storage battery is based on a familiar electrochemical principle first applied in 1800 by Volta: Two unlike metals, or unlike forms of the same metal, separated by a porous non-conductive material will, when immersed in an electrolyte, cause an electric current to pass through an external connecting circuit.

The plates of the storage battery are dissimilar forms of lead; the electrolyte is dilute sulfuric acid. The chemical reactions taking place in a storage battery are shown in the diagram at right, and are also expressed as an equation in this advertisement's heading. Reading from left to right, the equation shows the reactions involved in discharge. Passing an electric current through the battery in a direction opposite to that of discharge reverses the action. Read from right to left, the equation thus shows the reactions involved in charging.

Electrical energy in the battery is produced as a result of changing one atom of metallic lead and one molecule of lead peroxide into two molecules of lead sulfate. The metallic lead loses two electrons which convert the lead peroxide to lead sulfate. It is the transfer of these electrons in the circuit which causes the flow of current. The manufacture of battery plates has, for many years, consumed about one-third of all the lead used in the United States. The choice of materials for the storage battery's major elements was based on the following premises: The chemical reaction involved had to be a reversible one so that the battery could be recharged. The materials had to be abundant in nature, available for use in large volume; they had to be resistant to attack by the electrolyte and so related to each other in the electrochemical series as to present the greatest potential (voltage) difference.

Lead meets all these exacting requirements excellently. Of the common metals, it has the highest resistance to sulfuric acid. It is relatively abundant in nature and moderate in cost. It is one element which occurs in two chemical valences and thus provides a relatively high potential difference (2-volts). Last, but not least, around 85% of the close to 300,000 tons of lead used annually in the manufacture of batteries is reclaimed within 2 or 3 years and returned to the market. This use of lead is therefore recurrent and plays a key role in the conservation of the nation's mineral resources.

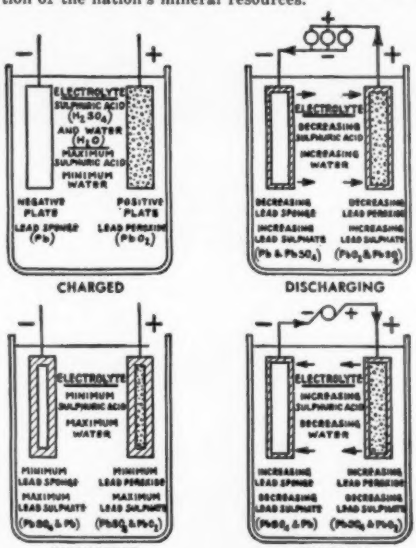
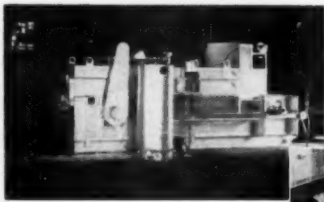


Diagram showing essential action in storage battery.
Courtesy: The Electric Storage Battery Co.


From Bumper to Tailgate . . .
Reduces Deadweight and Increases Durability
N·A·X
HIGH-TENSILE STEEL
The widespread use of N-A-X HIGH-TENSILE steel in transportation equipment emphasizes two vital characteristics of this high-strength low-alloy steel.
1. Strength with less deadweight. N-A-X HIGH-TENSILE steel reduces deadweight . . . of great importance in transportation equipment and military vehicles.
2. Exceptional durability. N-A-X HIGH-TENSILE steel, with its high strength and toughness, has proved greater resistance to fatigue and impact at normal and sub-zero temperatures. Its inherent structure and composition greatly reduce the effects of abrasion and corrosion.
The response of N-A-X HIGH-TENSILE steel to severe cold-forming operations and its excellent weldability by electric arc or resistance, atomic hydrogen or heliarc, and all other processes, are added important characteristics of N-A-X HIGH-TENSILE steel.
SCRAP
STEEL
The "Eager Beaver"
The use of low-alloy, high-strength steels in military equipment assures longer life with less deadweight.
GREAT LAKES STEEL CORPORATION
N-A-X Alloy Division • Ecorse, Detroit 29, Michigan
NATIONAL STEEL CORPORATION

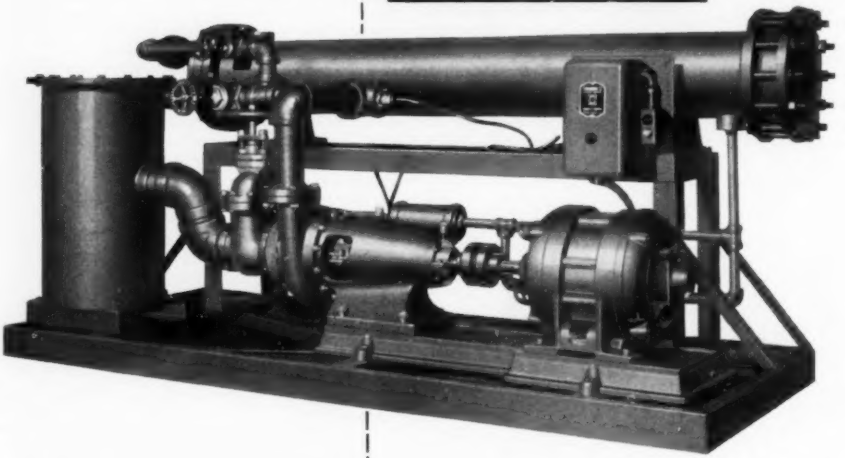
Controlled Quenching... Expertly Engineered



WE SURVEY . . . A B & G representative, in consultation with your engineers, examines your plant layout and determines what results are desired in your heat treating department.

WE ENGINEER . . . From data accumulated in your plant, the B & G engineering staff designs a complete quench-oil system, tailored to your specific requirements.

YOU RECEIVE . . . A complete recommendation as to size and type of equipment needed is delivered to you promptly. The only remaining step is to install the equipment.



B&G SERIES 1522 PUMP
One unit of a complete line of centrifugal pumps—catalog on request.

The quenching stage of your heat-treating process is the point where all previous operations are brought to either a successful or unsatisfactory conclusion.

At this point is determined the *final* quality of your product . . . the amount of time and material wasted by sub-standard rejects . . . and *your ultimate operating cost!*

When you install a B & G *Hydro-Flo* Oil Quenching System you are assured of uniform quality because *identical conditions* are maintained through every moment of the quench period. Positive circulation and proper turbulence of the oil maintains the desired temperature in all parts of the quench tank.

Write today for descriptive literature on B&G *Hydro-Flo* Quench Oil Coolers.

B & G

Hydro-Flo* **OIL QUENCHING SYSTEMS**

BELL & GOSSETT COMPANY

Dept. CE-16, Morton Grove, Ill.

*Reg. U. S. Pat. Off.

Heat-treating equipment since 1916

High Vacuum
helps this mechanical brain think clearly

high vacuum research and engineering

THIS little nest of relays is a "brain" which evaluates incoming impulses and issues orders to a mechanism that may be vital in a paper mill, a food processing plant, or an intercontinental bomber.

It took a great many human brain-hours to work out its intricate, compact mechanism. But a few fungus spores drifting in from a warm, humid atmosphere, a little dust, acid fumes, even rapid air pressure variations—any of these might undo the ingenuity that conceived it.

For security against these intruders, the relay manufacturer, C. P. Clare and Company, turned to the service offered by the Electro-Seal Corporation, Des Plaines, Illinois. Within a few minutes after Electro-Seal puts a DPi diffusion pump to work, all traces of moisture and 99.999 per cent of the air have been removed from the sealed assembly. Then a Consolidated Leak Detector is connected to the system and a jet of helium is played over the unit to check for leaks. (This instrument, which embodies another DPi high vacuum diffusion pump, can sound an alarm for a leak so small that a thimbleful of air would take 30 years to get through.)

Finally, Electro-Seal backfills with purified inert gas and sends the relay off to a long, useful life and duties for which an unsealed relay might be totally unfitted—demonstrating again how effectively DPi puts high vacuum at industry's service in a relatively new field, as we've been doing for years in the electron tube industry.

Perhaps we can help you, too. To find out, write to ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry

AJAX *Induction Furnaces*—

help HOOVER to cut die-casting costs by efficient melting and pumping of Aluminum

FIG. 1

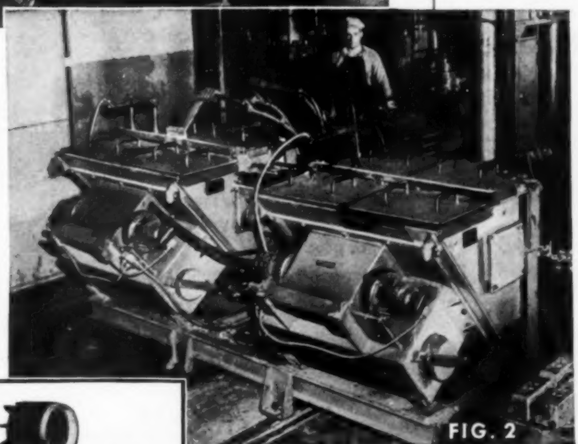


FIG. 2

FIG. 3

Fig. 1 shows nozzle of AJAX electromagnetic pump discharging metal into cold chamber of die-casting machine.

Fig. 2 shows AJAX melting furnace and electromagnetic pump installed in front of die-casting machine.

Fig. 3 shows Hoover squirrel-cage aluminum cast rotors.

CASE HISTORY

COMPANY: The Hoover Company, Kingston-Conley Division, Cambridge, Ohio, plant.

PROBLEM: To conserve scarce copper supply by use of aluminum as a substitute.

To cut die-casting costs in the manufacture of squirrel-cage induction motor rotors without sacrificing performance characteristics.

SOLUTION: Installation of the **LOEWY-HYDROPRESS** die-casting system, in which several sizes with various end ring designs are made in same die by simple change of inserts. **AJAX INDUCTION FURNACE AND ELECTROMAGNETIC PUMP** used to melt and pump high-purity aluminum. Low frequency induction principle with precise controls keeps metal at constant temperature. Automatic electromagnetic pump discharges exact amount needed to fill die, eliminating hand ladling.

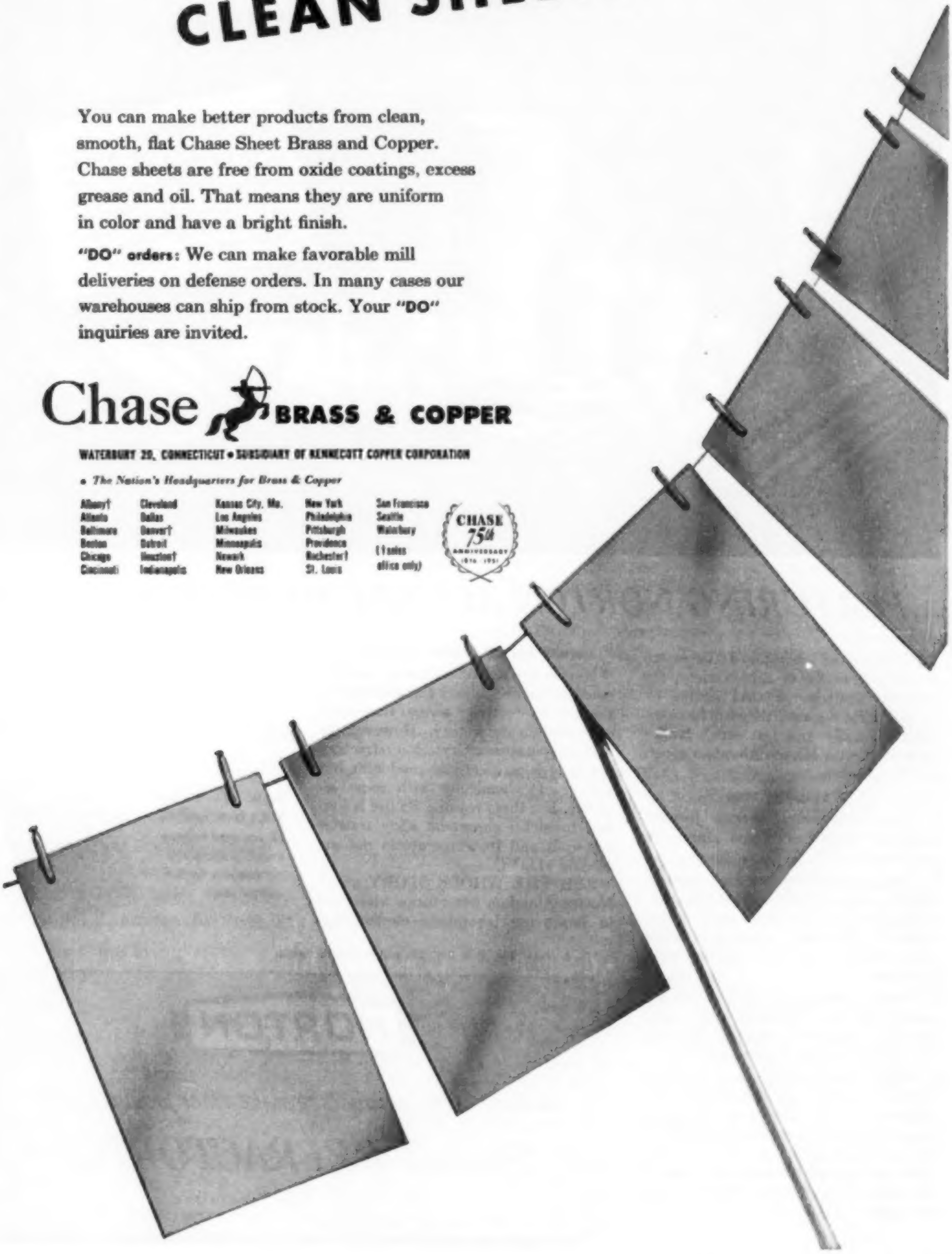
RESULTS: Combined melting and die-casting set-up so excellent that the Hoover plant converted completely to aluminum die-cast type within 2½ months.

AJAX ENGINEERING CORPORATION, TRENTON 7, N. J.

AJAX TAMA-WYATT

INDUCTION MELTING FURNACE

AJAX ELECTRO METALLURGICAL CORP., and Associated Companies
AJAX ELECTROTHERMIC CORP., Ajax Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC., The Ajax Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax Wyatt Induction Furnaces for Melting



...FEATURING NORTON ALUNDUM* REFRACTORIES

Whether your laboratory furnaces are of the pot, muffle or tube variety, for chemical analysis, physical testing or metallurgical research, they will function more efficiently and last much longer when built with Norton Alundum cores, muffles or tubes.

4 REASONS WHY

1. Norton Alundum electric furnace parts are made from fused aluminum oxide that is 99% Al_2O_3.

2. *Such purity results in a high degree of stability and chemical inertness* that prevents reactions with either resistor materials or platinum, nickel, and fused oxide crucibles and boats at high temperatures.

3. *Norton Alundum furnace shapes are excellent thermal conductors*, thus assuring small temperature gradient between the resistor and the furnace interior.

4. *Norton Alundum refractory is a good electrical insulator up to relatively high temperatures.* One test on an Alundum tube shows a direct current resistance of 7.5×10^7 ohms/cm^3 at 600° C. This value did not fall off materially until a temperature in excess of 1600° C was reached.

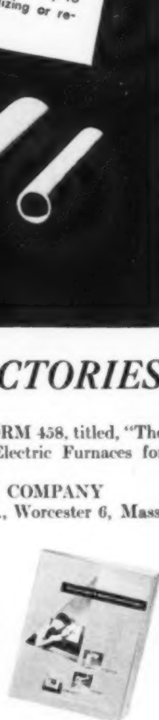
WHAT ABOUT SILICON CARBIDE?

Norton Crystolon* refractory muffles, made of bonded silicon carbide, have a thermal conductivity several times that of Alundum refractory. However, at high temperatures, Crystolon refractory not only is an electrical conductor but also reacts chemically with some resistors. For these reasons, its use is limited to nickel chromium alloy resistor materials and to temperatures not exceeding 1150° C.

FOR THE WHOLE STORY about Norton Alundum refractories' vital part in improving laboratory electric furnaces, write for FORM 458, titled, "The Construction of Electric Furnaces for the Laboratory."

NORTON COMPANY
326 New Bond St., Worcester 6, Mass.

NEW 24-PAGE BULLETIN tells you all you need to know about building electric furnaces for laboratory use.



*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

NORTON

TRADE MARK REG. U. S. PAT. OFF.

Making better products to make other products better

Special REFRACTORIES

Canadian Representative
A. P. GREEN FIRE BRICK CO., Ltd. TORONTO, ONTARIO

Metal Progress

Vol. 60, No. 3 · September 1951

ERNEST E. THUM, *Editor*

JOHN PARINA, JR., *Associate Editor*

Cover design (robot arms in hot laboratory) by Peter Duly

Technical Articles

Correspondence

Departments

Abstracts of Important Articles

Continued high steel production this winter may depend on . . . CLEANING OUT YOUR SCRAP THIS MONTH

HOW TO TURN SCRAP INTO MONEY with an organized dormant scrap round-up in your plant:

1. Appoint a top executive with authority to make decisions to head the salvage drive.
2. Organize a Salvage Committee and include a member from every department.
3. Survey and resurvey your plant for untapped sources of dormant scrap. Encourage your employees to look for miscellaneous scrap and report it to the committee.
4. Sell your entire organization on the need to scrap unusable material and equipment.
5. Prepare a complete inventory of idle material and equipment. Tag everything not in use.
6. Start it back to the steel mills by selling it to your regular scrap dealer.
7. **KEEP AT IT!**

*****DORMANT SCRAP** is any obsolete, broken or worn-out and irreparable machinery, tools, equipment, dies, jigs or fixtures, etc., that may encumber your premises.

Despite . . . and because of . . . the continued high rate of steel production, the steel industry is on a hand-to-mouth basis in its receipts of purchased scrap . . . *essential to production!* Mills that normally inventory a 60 day supply of scrap, are now maintaining high production with less than a week's supply on hand. *That the effect of winter on transport facilities could quickly exhaust these dangerously meager scrap inventories . . . and thus force a cut in steel production . . . is obvious.* Help assure an uninterrupted steel supply by rounding up and selling your dormant scrap* to your regular scrap dealer *this month!*

INLAND

INLAND STEEL COMPANY

38 South Dearborn Street • Chicago 3, Illinois

Titanium in Aircraft

By J. B. Johnson* and E. J. Hassell*
Metallurgy Group
Wright-Patterson A. F. Base
Dayton, Ohio

THE UNITED STATES AIR FORCE became acutely aware of the dependence of large-scale aircraft production on a continuous supply of raw materials in 1942 and 1943 when a shortage of aluminum appeared imminent. The supply of South American bauxite had been reduced to a trickle. Fortunately, ore supply was supplemented by the increased production and beneficiation of lower grade domestic ores, and castings, rolled, extruded and other forms were made available by the construction of new plants and improved allocation of available products. The possibility of even greater demands on this country's mineral resources was envisaged, and immediately upon cessation of hostilities the Air Force sponsored a survey of the resources in continental North America. Its purpose was to investigate metals obtained from these minerals which might replace or augment those in short domestic supply.

One of the metals which gave promise of meeting the requirements for a structural material for aircraft and engines was titanium. The principal ores, rutile and ilmenite, occur rather abundantly in accessible deposits near the St. Lawrence in Quebec; Canada's total reserves of titanium metal are estimated at 105,000,000 tons. Virginia, New York, Wyoming, Florida and North Carolina have proven ore deposits in that relative order of importance; estimated metal in these deposits amounts to 5,400,000 tons. The titanium metal reserves on the continent are, therefore, equal to more than 100 years' supply at the maximum production rate for aluminum reached during the war. The mining and smelting of titanium-rich ores had been developed on a large scale for paint pigments. In fact, the production of titanium dioxide in 1946 closely paralleled the maximum production of alumina before the war. Titanium could thus be classified as a "nonstrategic" metal, when measured by the yardstick of the availability of domestic ores.

Wilhelm Kroll and the staff of the U. S. Bureau of Mines had developed a process for the production of ductile titanium in 1940. Briefly, the method consists of the reduction of titanic chloride to titanium sponge with an excess of magnesium in a helium atmosphere at about 1550° F. The excess magnesium is then dissolved in hydrochloric acid, and wrought products made from sintered compacts of the resulting titanium powder. The forging and rolling characteristics, corrosion resistance, and mechanical properties were favorable. Battelle Memorial Institute, under a RAND contract of the United States Air Force, also investigated arc-melting procedures for this powder and were successful in producing titanium and titanium alloy ingots. This process has been successfully adapted to commercial production. Several well-organized firms are now in the business, and a limited amount of titanium alloys made by various techniques is available for test and small-scale use.

Strength-to-Weight Ratio—An engineering material must have structural efficiency to give satisfactory service. The primary consideration is, generally, adequate mechanical properties, but in aircraft applications weight also controls efficiency and the strength-to-weight ratios are always referred to in any discussion concerning the comparative merits of different metals.

For comparison, the strength properties of light aircraft structural sheet materials at several temperatures are listed in Tables Ia and Ib. The ratios, which are the uni-axial stresses in tension (or compression) divided by unit weight, actually rate the materials when they are used in components subjected to tensile loads (or to block compression loads without buckling). The relative magnitude of the tensile strength-weight ratios are displayed in Fig. 1 so the materials can be visually compared at each of the three temperatures.

If the metals are evaluated as to ability to resist column buckling or plate buckling, the order may be somewhat different. However, there are many examples of aircraft components, such as wings, fuselages and control surfaces, which have been fabricated from either high-tensile Type 304 stainless steel (18-8), 24S-T aluminum alloy, or AZ31X magnesium

*Mr. Johnson is chief and Mr. Hassell is metallurgist in the Metallurgy Group, Flight Research Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base.

Table Ia — Strength of Aircraft Structural Metals at 70° F.
First five lines from ANC-5a, "Strength of Metal Aircraft Elements", 1949

Metal	Density d Lb./Cu.In.	Properties in Tension						Compression	
		Modulus E 10^6 Psi.	$\frac{E}{d}$	Ultimate T.S. 10^3 Psi.	Yield Y.S. 10^3 Psi.	$\frac{T.S.}{d}$	$\frac{Y.S.}{d}$	Yield C.Y.S. 10^3 Psi.	$\frac{C.Y.S.}{d}$
Type 304 stainless steel (full hard)	0.286	26.0	90	185	140	647	490	105	367
Type 347 stainless steel (annealed)	0.286	29.0	101	75	30	262	105	35	122
Aluminum alloy 24S-T4 (bare)	0.100	10.5	105	68	51	680	510	42	420
Aluminum alloy 75S-T6 (bare)	0.101	10.3	102	82	72	810	710	72	710
Magnesium alloy AZ31X	0.0645	6.5	101	39	29	600	450	24	372
Titanium metal (annealed)*	0.163	15.0	92	80	70	490	430	70	430
Titanium alloy RC-130A†	0.163	16.0	98	150	130	920	800	135	827
Experimental titanium alloy‡	0.163	16.0	98	190	170	1160	1040	170	1040

*"Technical Information on Titanium Metal", Remington Arms Co., Inc.
†Data from Rem-Cru Titanium Co.
‡"Research and Development on Titanium Alloys", Battelle Memorial Institute.

alloy to meet the same static and dynamic load requirements. On test, these assemblies supported equal loads and the weights were the same, within production tolerances. When the ratios of modulus to density are approximately equal (90 to 105, as in Table I), the ratios of uni-axial allowable stress to density can be assumed to indicate an accurate rating for alternate materials when applied to complete assemblies, even though the several details on parts in these assemblies may be designed to carry a combination of tension, compression, shear and buckling loads.

This analysis would indicate that a variation of less than 100 in the ratio T.S./d is not too significant, since the three metals noted above fall within the range of 600 to 680 at room temperature (Table Ia); a difference of over 100, however, is significant. For example, components originally fabricated from 24S-T with T.S./d = 680 have been redesigned using 75S-T with T.S./d = 810, and weight savings have accrued. The lower rating of commercially pure titanium at room temperature (T.S./d = 490) as an alternate for the basic structural metals, 75S-T, 24S-T, Type 304 stainless, and AZ31X, is illustrated in Fig. 1.

The comparison of commercial titanium with annealed Type 347 stainless steel (18-10, stabilized) is favorable, and most of the present applications of this grade of titanium have been made on a volume-for-volume substitution and, consequently, with an appreciable reduction in weight of the component. This usage is quite restricted and affects only a small percentage of the total airframe weight. It is confined, generally, to those parts operating at temperatures above 250 to 300° F. The advantage is maintained at 300°, but practically nullified at 700° F.

Type 304 stainless (18-8) has a more favorable position in the series of alloys when appraised at 300 and 700° F., but this may be somewhat misleading since the higher mechanical properties are due to cold work and the values in Fig. 1 are taken from short-time elevated temperature tests. Comparison on the basis of data for stress-rupture tests for long periods would probably show a greater decrease for the Type 304 stainless as compared to titanium.

Experimental Titanium Alloys — Titanium alloys have considerably higher ratings at all three temperatures. This fact and the high corrosion resistance have generated a great deal of interest in titanium-base alloys in the aircraft industry. Titanium alloy RC-130A was selected as representative of several available alloys now in production with similar properties. An alloy with these mechanical properties is useful for many statically and dynamically loaded parts in airframes and engines where the operating temperatures do not exceed 700 to 800° F.

Table Ib — Strength of Aircraft Structural Metals at 300 and 700° F.

Tests at 300° F.				Tests at 700° F.				Metal	A.M.S. Spec. *(a)*
Ultimate T.S. 10^3 Psi.	Yield Y. S. 10^3 Psi.	$\frac{T.S.}{d}$	$\frac{Y.S.}{d}$	Ultimate T.S. 10^3 Psi.	Yield Y.S. 10^3 Psi.	$\frac{T.S.}{d}$	$\frac{Y.S.}{d}$		
146 *(b)*	—	510	—	128 *(b)*	—	445	—	Type 304 stainless steel (full hard)	5519
75 *(c)*	34	260	120	67 *(c)*	32	235	110	Type 347 stainless steel (annealed)	5512
42 *(d)*	37	420	370	5	3.5	50	35	Aluminum alloy 24S-T4 (bare)	4037
25 *(d)*	22	250	220	6.5	5	65	50	Aluminum alloy 75S-T6 (bare)	4045
22 *(d)*	13	340	200	4	2	60	31	Magnesium alloy AZ31X	4376
60	42	370	260	36	20	220	120	Titanium metal (annealed)	—
125	100	760	610	100	70	615	430	Titanium alloy RC-130A	—
160 *(e)*	130	980	790	125	90	760	550	Experimental titanium alloy	—

(a) Aeronautical materials specification of Society of Automotive Engineers.

(b) Calculated from shear properties at elevated temperatures. See "Nickel Alloy Steels", 2nd edition, 1949, International Nickel Co., Inc.

(c) "Steels for Elevated Temperature Service", United States Steel Co.

(d) High-temperature properties from "A.S.M. Metals Handbook", 1948 edition.

(e) High-temperature properties estimated from corresponding values for RC-130A.

It is also possible that an alloy of aluminum will be developed which will have a strength-weight ratio at room temperature equal to or higher than titanium alloy RC-130A. Unfortunately, the strong alloys of the aluminum-zinc-magnesium ternary system lose strength rapidly with increasing temperature. Since this system has produced the alloys having the highest mechanical properties at room temperature, it will be necessary to develop another system if aluminum alloys are to be used in structures working at elevated temperatures.

The titanium alloy referred to as "experimental" in Table I is representative of several which have been produced in the laboratory in the form of rolled strip. Their ductility (as measured by elongation and bend tests) is low, and the ratio of yield strength to tensile strength is high — both factors which increase the difficulties in forming unless the alloys are amenable to annealing for softening, and subsequent hardening *after* forming. Many constitutional diagrams for binary alloys have been determined in the high-titanium region, and the

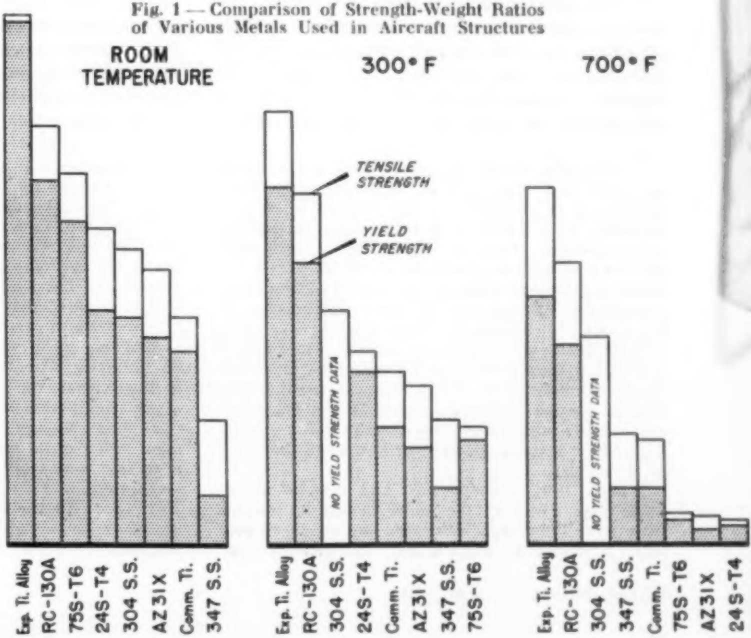


Fig. 1 — Comparison of Strength-Weight Ratios of Various Metals Used in Aircraft Structures

possibility of heat treating to improve the tensile strength is not attractive, but sufficient work has been done on ternary and more complex titanium alloys to warrant considerable optimism that a high-strength production alloy will be developed. The problems to be surmounted are similar (for the most part) to those previously solved in the production and utilization of alloys of other metals.

COMMERCIAL DEVELOPMENT

"Titanium melts at a high temperature (3150° F.) and, when molten, reacts with virtually everything it touches. Some gases and metallic elements have important effects when present in the solid metal; for instance, small amounts of oxygen and nitrogen decrease the ductility markedly. Furthermore, specimens prepared by sintering and those made by melting may differ considerably in their properties. But after all due allowances are made for present uncertainties, titanium is still a light, strong, ductile, corrosion resistant metal whose structural applications will depend largely on getting the cost of the metal down from its present high level of $5 a pound. Just how soon titanium will come into widespread industrial use will depend also on the development of titanium alloys for specific purposes. Considerable progress in alloying is reported, and serviceable titanium alloys are in prospect, both for use at normal and at elevated temperatures."

The above quotation from the March 1949 issue of *Metal Progress*, a foreword to a series of articles on titanium and titanium alloys, fits the situation today as well as it did then. The demand for commercially pure titanium, either for aircraft or other engineering applications, will not be sufficient to build up a large producing industry. *Alloys* must be developed for specific purposes. The successful alloys will be those which can be used by engineers to improve the performance of a machine or structure, increase its life, or show some other tangible gain for the money expended. Titanium alloys are expensive; it may be that the aircraft industry can pay more per pound for a desirable material, but in the final analysis that material must still earn its keep.*

A survey of past history indicates that no new material completely replaces all other materials in an aircraft structure. The new one is first used with considerable caution and for a few components where the largest weight savings are evident. It requires from five to seven years to get a new structural material with proven superior properties into production in airplanes or engines in relatively large quantities — and by that is meant more than 5 to 10% of the total weight.

Titanium has become part of the rearmament program and the time factor in its utilization may be reduced by accelerating the development of new reduction processes for sponge, and of better melting practices and fabricating procedures in mill and factory. All of these will doubtless result from the large funds being expended by private industry and the government. Currently, the very small commercial usage is an offsetting factor. It is doubtful if the demand for munitions alone can create a very large producing industry. Commercial usage in peacetime products is essential. This requires not only a competitive price with other materials, including a good scrap market, but also continuous output of engineering data on forming, machining, joining, and finishing

*EDITOR'S FOOTNOTE — A Yankee guess might be made as to the cost of titanium metal when production is measured in tons instead of pounds annually, by drawing a parallel with magnesium and aluminum. Prior to World War I, magnesium was imported from Germany at $1.65 per lb., a value on the same order of magnitude as titanium's present cost of $5.00 per lb., when depreciation of the money is considered. Dow Chemical Co. was able to break even on its costs in 1926, when it produced 100 tons of magnesium and sold it at 69¢ (approximately $1.50 in present money). 1950 cost of magnesium ingot was 24.5¢ per lb., when made at the rate of 24,000 tons per year — an example of how mass production brings down the price of an article.

Since 1 lb. of magnesium and 1 lb. of aluminum require nearly the same energy to reduce them from their ores — chloride and oxide, respectively — it may be guessed that the eventual price of magnesium will equal that of aluminum, which is now 19¢ per lb. with U. S. production of about 650,000 tons per year.

Titanium is not an easily reduced metal; although the heat of formation of the chloride is somewhat less than that of magnesium chloride. Likewise it has a very high melting point. When it is considered that (in the Kroll process) it takes 1.1 lb. of Mg to produce 1.0 lb. of Ti, it can be concluded that the price of the two will eventually be on the same order. One can therefore guess that in 1953 (when, for example, Titanium Metals Corp. of America plans on making 3600 tons in the wartime Basic Magnesium plant in Nevada) titanium ingot will cost on the order of $2.00 per lb., — that is to say, somewhat more than Dow's 1926 cost of magnesium, in 1950 dollars.

P. S. — All the above thinking is about *ingot*. The usual large multiplying factors must be used to compute the selling price of fabricated articles.

which must be channeled into design handbooks and drafting room manuals.

It is recognized that present methods of melting and casting are not entirely satisfactory. A great deal more will have to be learned concerning processing and fabrication before finished products of this new material can be made with a uniformly high quality in the amounts necessary to meet the potential demand.

Nevertheless, the fact remains that titanium and a number of its alloys possess unusually attractive properties as structural materials. They are inherently stable, that is, resist corrosive attack in environments where structural materials are normally used. Titanium has a higher melting point than iron, and eventually alloys should be developed with good mechanical properties and oxidation resistance in the range of 800 to 1200° F. and possibly up to 1800°. At room temperature and up to 800°, alloys are now available with excellent mechanical properties.

Improving Bendix Airplane Landing Wheels by Burnishing

By W. H. DuBois
Chief Engineer
Airplane Wheel & Brake Div.
Bendix Aviation Corp.
South Bend, Ind.

An article in the August issue of *Metal Progress* by George H. Found of Dow Chemical Co. (p. 51) discussed methods of increasing the endurance of magnesium castings by surface work. It will now be my purpose to bridge the gap between the laboratory tests he reported and the shop use of surface treatment. This discussion, therefore, will describe tests on full-scale models of relatively complicated aircraft wheels cast in magnesium alloys. Comparisons will be made of certain surface treatments — namely, ball peening, and burnishing or rubbing — and some remarks will be made about the difficulties and techniques involved. We will also outline some of the conclusions determined by the Bendix Products Division and the feasibility of using these treatments on production parts.

It should be pointed out at the beginning that our work may be considered inconclusive from the standpoint of number of tests made. While it may be practical to run a large number of identical test bars at the same load condition, this is not true on full-scale aircraft wheels. In the first place, these tests are slow and expensive. We use the specially designed machine shown in Fig. 1; it cost approximately $50,000 and requires two men to operate it. About the best we can do on an aircraft wheel of average size is to roll 100 miles in a 24-hr. day. Aircraft tires, as now designed, are not made for continuous high-speed service and therefore have very short life under the test conditions; failure may be expected at from 50 to 300 miles. There is considerable doubt about the real effect of sudden release in load in this machine which occurs when a tire blows out. This may have considerable effect on the ultimate service life of the wheel. In the second place there is the difficulty in duplicating test pieces. Although machining dimensions may be held quite accurately, variations in the wall sections at critical areas in a sand-cast wheel may reach a considerable percentage. This will affect the ultimate life of the part materially. Unquestionably, the totality of casting variations — soundness, porosity, nicks on the surface, over-all finish smoothness — have a large effect on service life. All this should be pointed out, since each of these items will have a bearing on the conclusions drawn from tests.

Early in 1946, the Bendix Products Division was ready to accept the statement that surface treatment had much to do with ultimate service life. We felt this was particularly true in aircraft wheel design, as we possessed some rather perplexing information on wheel failures wherein fractures had occurred at sections where strain gages showed relatively low stresses (4000 to 5000 psi.) and others where failures did not occur in sections

stressed as high as 10,000 to 11,000 psi. We were led to the belief that actual failures started from some defect in the outer fiber or at the surface. For example, improper cleaning of sand from the ribs of a wheel casting is a very important contribution to failure. Blowholes, excess porosity of the surface, core matching lines, and many other common defects of this nature would seriously affect the ultimate fatigue life. We had also concluded it was not always sufficient to add metal at the point of failure, provided the surface defect remained. In other cases, it was impossible to decrease the working stress at particular points of failure, such as at the radius between the bead seat and vertical flange section, because such radii are dictated by tire designs.

Burnishing — One of the required tests is that aircraft wheels must endure a roll test of 1000 miles minimum at their rated capacity without failure. When our 17.00-20 wheel was increased in capacity from 20,500 to 25,000 lb., fatigue failures occurred in the demountable flange in the radius between the bead seat and vertical flange section (Fig. 2). Inasmuch as there are many of the wheels rated at 20,500 lb. in service, interchangeability of flanges between the designs was desirable, thus making it impossible to increase the section at the point of failure, and it was necessary, therefore, for the part to carry a larger stress in this region.

Table I shows tests which demonstrate the effect of burnishing at the critical section. The first test was on a standard wheel with a machined but unburnished flange; it will be noted failure occurred at 300 miles. The second test was essentially the same wheel design but particular care was taken to get a smooth section at the point of expected failure and also to get the best fit between flange and cylindrical barrel of the wheel. Here failure occurred at 813 miles.

The third test was on the same wheel and flange design with the exception that an annular groove was cut on the inside diameter of the demountable flange so as to relieve the stresses at the critical section in the radius. Here failure occurred at 1005 miles by a crack in the relief groove. This cannot be considered as comparable for the reason that it incorporated a design change. It would better be said the life of the machined flange of standard design without burnishing was somewhere between 300 and 813 miles under the test conditions. Further tests and experience on this flange would indicate the higher value (800 miles, approximately) is more indicative of true service life.

The fourth test shown in Table I was the first attempt at using a burnished flange. The surface of this flange (of which four sections were cut after the test) was burnished between points A – A in Fig. 2. At 1000 miles there were no cracks evident. The first indication occurred at 1100 miles, with a very small crack in the critical section. The test was carried on to 1250 miles before the crack had extended to the dangerous point. Minute inspection then indicated

Fig. 1 — Machine for Testing Performance of Aircraft Landing Wheels

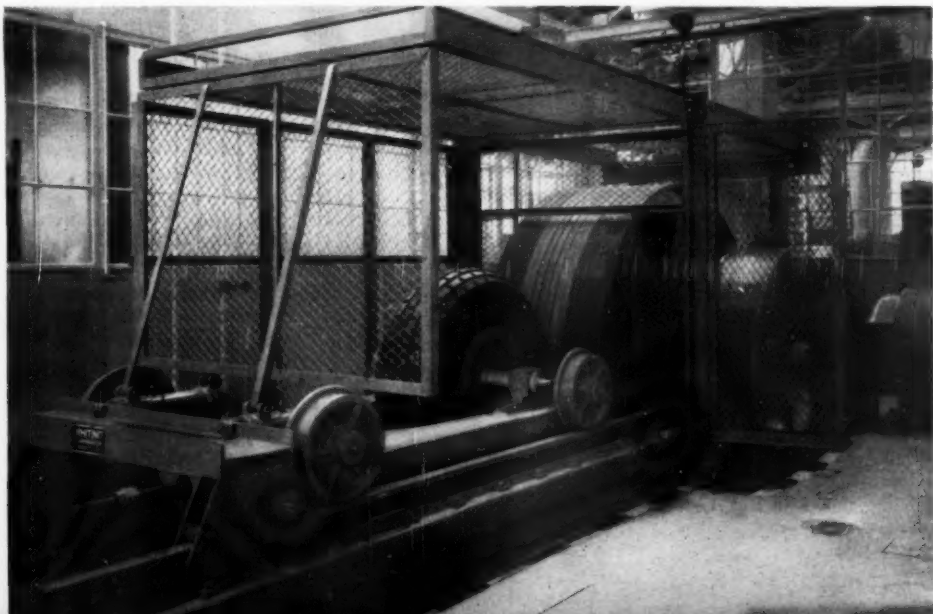


Table I — Life of Machined and Burnished Flanges on 17.00-20 Wheel Loaded to 25,000 Lb.

Test	Tire Pressure	Finish	Miles	Condition
No. 1	Unknown	Machined	300	Small cracks at bead seat radius
No. 2	108 psi.	Machined	813	Small cracks at bead seat radius
No. 3*	105 psi.	Machined	1005	Crack in relief groove
No. 4	—	Burnished	1000	No cracks
			1100	Small cracks in area of light burnish
			1250	Area of failure slightly increased
No. 5	103 psi.	Burnished	1700	Fine cracks at bead seat radius
No. 6†	100 psi.	Burnished	1700	Fine cracks at bead seat radius through area containing microporosity

*Design change — groove machined on inner surface of flange to relieve stresses on bead seat radius.
†Salvage test on flange rejectable because of undue microporosity shown by radiograph.

that a perfect job of burnishing had not been done, primarily due to the method of mounting and a slightly out-of-round condition of the flange. In other words, rubbing had not been consistent throughout the complete periphery. As might be expected, the failure occurred at the spot where the burnishing treatment was the least effective or had the least penetration.

The next test used a burnished flange but care was exercised to improve the burnishing technique to obtain uniform surface working. The results were quite satisfactory; the flange went 1700 miles before showing any failure.

The final test was in the interest of salvage, to check the effect of rather heavy porosity (Fig. 2) considerably more than we would allow through our production standard. This flange was burnished the same as in the previous test. Here again the results were very gratifying, as we got the same amount of roll as in the previous test on a standard flange with a minimum of porosity. A microscopic examination of this flange after the test revealed heavy porosity, but it did not extend to the surface adjacent to the starting point of failure; consequently it should not have influenced fatigue properties adversely.

The complete program on the 17.00-20 wheel required some eight months to complete and included many runs other than those listed in Table I. These additional tests incorporated design changes as well as changes in surface treatment, and the conclusions drawn from them are not entirely conclusive, as it is hard to evaluate which change was responsible for an increase or decrease in the fatigue life. It can be stated, however, that burnishing always seems to have a positive effect toward increasing service life. Table I itself would indicate an increase in ultimate life of the flange from 800 to 1700 miles — approximately double.

Another critical section is in the retainer ring groove of the wheel proper, a semicircular groove matching the region marked C in Fig. 2. We tested a 34 x 9.9 wheel assembly similar in design to the 17.00-20 size already discussed. The first test cracked in the machined retainer ring groove at 810 miles. The second test on a (commercially) identical wheel showed 570 miles; a crack developed in the internal ribs. The third test (also with as-machined groove) cracked in the groove at 925 miles. In the fourth test, when the retaining ring groove was burnished and the assembly tested under the same loading conditions, the wheel went 1250 miles without trouble in the burnished groove, but the wheel cracked in an internal rib.

It would seem from these data that the expected life in the retainer ring groove section on the as-machined wheel was approximately 925 miles. With the burnished section, we can only conclude that the fatigue life is more than

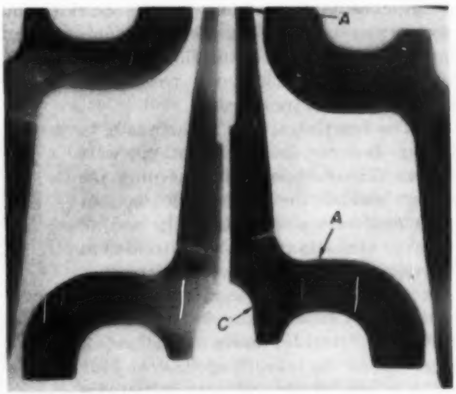


Fig. 2 — Radiographs of Four Sections Cut From Test 6 (Table I) Showing Cross Section of Flange, Extent of Burnished Surface, and Location of Fatigue Cracks Near Bead Seat Radius. Surface A-A is burnished; surface C mates semicircular groove in wheel rim to house a retainer ring

1250 miles, as no failure occurred up to this point. Again we must conclude that the burnishing operation materially increased the service life of the wheel, although it isn't conclusive *how much* this life was increased.

SHOT PEENING

Our experience with shot peening had not been as extensive or as conclusive, since it is confined to four tests on the 17.00-20 wheel, sand cast in magnesium alloy. Testing conditions were uniform, the average tire pressure being 115 psi. and the wheel loading being 31,500 lb.

Test A was stopped at 727 miles when cracks were discovered through the valve stem hole, extending 10 in. around the perimeter and into the inner ribs. This casting had no surface treatment.

Test B was also on an as-cast wheel. At 787 miles small cracks were found in the valve stem hole, and at 920 miles one crack had progressed 2 in. and extended into an inner rib. A crack was also found in the retainer ring groove.

Test C was the same except that the inboard spokes were smoothed by hand with emery paper and the window radii made more definite. This run was stopped at 731 miles, when small cracks were found on two inboard spokes.

These first three tests are essentially the same wheel design, tested under the same conditions. Life varied from 727 to 920 miles; two types of failure were indicated, one of a localized nature around the valve stem hole, and one of a more serious nature in the cracking of spokes and internal ribs. The latter may have been the result of inferior metal on the surface, or of internal stresses not relieved by heat treating.

The fourth test was unfortunate, in a way, because *two* modifications were made. The first was shot peening the spokes and all the internal rib sections with moderate sized shot. The second was a stabilization heat treatment intended to relieve any residual stresses. The combination of the two changes materially increased the fatigue life of the wheel. At 1351 miles a small crack appeared in the inboard spoke. At 1401 miles a 2-in. crack appeared in the rim at the valve slot which was the localized point of failure. Finally, at 1735 miles, the wheel cracked entirely through one spoke. It must be concluded, therefore, the combination of stabilization and shot peening more than doubled the life.

We did not go into production with shot peening because of the difficulties involved in effectively working the inside of the wheel with available equipment. It was almost impossible to direct shot through the small openings or windows in the side of the wheels and strike perpendicularly the ribbing at the critical section. The wheel might be mounted on an inclined spindle and the shot directed at an angle so that the internal ribs would be effectively peened, but the expense of such a setup and the possibility that it would still give inconsistent peening on the various sections of the wheel decided us against this procedure. Instead, the design was changed so as to increase the section of the spoke at the point of failure. When such a wheel was tested, after stabilization by heat treatment, it had approximately the same life as in the fourth test just described, so it was adopted as our standard production wheel.

We can only conclude from these results that shot peening is effective if carefully controlled and if the blow is perpendicular to the surface being treated. It does not work out too well for the inside of wheel castings, because of inaccessibility — yet this would be the ideal spot for such treatment, as it is impossible to machine or smooth these areas. Such surfaces should be peened only where they are essentially regular, with no high ribs adjacent to long sections of essentially flat nature.

Our experience has been mostly with fairly large shot — 0.032 to 0.055 in. It is very desirable to screen the shot at frequent intervals to remove any broken or fragmented shot.

Fig. 3 — Burnishing Tool Merely Replaces Cutting Tool and Automatically Generates the Same Surface on the Outside of the Flange

PRODUCTION BURNISHING

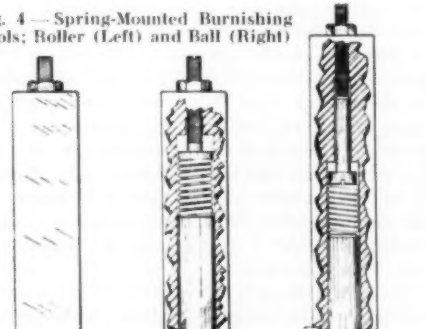
Our laboratory experience of burnished wheels and flanges warrants its use on all magnesium wheels in production except the smaller sizes where minimum sections dictate a conservative low-stressed design.

Wheels are machined in lathes equipped with profile templates for a single finishing cut over the entire rim. We intended to use the same equipment, in the same setup, substituting a burnishing tool for the normal cutting tool. (See Fig. 3.) This required a tool with circular end and a spherical burnishing tool so the same surface would be generated with both. The radius is the most critical section of the entire rim profile and should be a *generated* burnishing operation instead of a series of concentric burnished rings. While tools must be sharper in curvature than the radius on the part itself, they should be kept as close as possible to the actual machined radius.

A series of tests was set up on production machines with speeds ranging from 57 to 1050 ft. per min., and feeds from 0.016 to 0.005 in. per revolution. Maximum penetration of burnishing tool was attempted, but if 0.003 in. it galled the metal. Most satisfactory penetration was 0.002 to 0.003 in. The highest speeds and the lowest feeds gave the best appearing surface. A spring-loaded burnishing tool (Fig. 4) will compensate for any out-of-round condition. A spring with a relatively low rate of response will follow surface variations with little change in actual load.

A study was also made of lubricants. We found that petrolatum, brushed on the surface, worked much better under the burnishing tool than a machining oil or other liquid lubricants.

Fig. 4 — Spring-Mounted Burnishing Tools; Roller (Left) and Ball (Right)



The question may well be asked as to how we determine when a surface is properly burnished. A fair job can be done by visual inspection, because it will be smooth, with no indication of tear, and glazed slightly. This is particularly evident under low magnification. The correctly burnished surface has the appearance of a series of furrows turned over, with no fragmentation or loose chips in evidence. However, it is necessary to section a piece occasionally, polish and etch it, and then examine it microscopically. This shows very clearly the depth of penetration by strain markings in the grains near the surface. (See the photomicrographs in Mr. Found's article last month.) Such metallographical studies are highly recommended when evolving a technique to burnish a surface on a newly designed part. It is also important to start with a comparatively smooth machined surface; our specification calls for a 100-microinch finish. Yet we know of no inspection quite as good as that of the good operator. It might be said that a good-appearing surface is generally a good burnished surface.

CONCLUSION

Wheel designs are at best a compromise. One set of requirements dictates a strong rigid structure capable of withstanding five to ten times the normal rated load of the wheel. Since weight must be saved, this rigidity can be provided most efficiently through high ribbing and spokes. Yet a second set of requirements specifies long service life (resistance to fatigue). Warranties are being requested for service life of 10,000 miles rolling distance for landing, taxiing, and take-off operations. Here we should have a different structure, one of uniform sections throughout the circumference, a structure that yields uniformly without points of high stress concentration. Again, the wheel is a running mate of the tire, and the entire rim profile must be compatible with good tire design.

The result is that aircraft wheels are rarely ideal structures from the standpoint of longevity, due to the compromises in the design and resulting points of high stress concentration. Moreover, cast magnesium alloys are unquestionably somewhat notch sensitive, and should any smooth surface be interrupted at a point of high stress the result will be short life. Any surface treatment such as burnishing or ball peening that compensates for notch sensitivity and other factors contributing to scatter of test data, unpredictability, and short fatigue life should be a *must* in the design.

Production of Powdered Uranium and Thorium*

By P. Chiotti
and B. A. Rogers
Ames Laboratory
Iowa State College

THE following is a description of the method of making powdered uranium and thorium which is used at the Ames Laboratory. This laboratory has prepared several batches of these powdered metals in response to requests from other units of the Atomic Energy Commission. The conversion to the powder form, done with ordinary laboratory equipment and in a short time, is simple. As an amount sufficient for some purposes can be made up in less than half a day, the powdered metals may be considered as always immediately available if one has the requisite massive metals on hand.

To prepare either powder, one needs only to allow the starting metal to react with hydrogen to produce the hydride, which forms as a powder, and then to decompose the hydride under conditions such that no sintering occurs. The production of powdered uranium is particularly simple and will be described first. For reasons that will become apparent, thorium presents a slightly more complicated problem.

PRODUCTION OF POWDERED URANIUM

The natural division of the process into two stages may be followed conveniently in an explanation of the operations. The reaction between uranium and hydrogen produces uranium hydride, UH_3. This compound forms as a powder so fine that it will pass a 400-mesh screen and has so little adhesion to the metal that it falls away continuously leaving a freshly exposed surface. Three principal factors controlling the rate of reaction between uranium and hydrogen are *(a)* area of surface of metal, *(b)* temperature of the reacting substances, *(c)* pressure of hydrogen over the charge.

When the second and third factors are constant, the rate of reaction is proportional to the exposed area. For this reason, lathe turnings, pieces of thin sheet, or other subdivided forms of metal are converted more rapidly than the same weight of uranium in a single block. Thin flat pieces have the advantage also that the area available for reaction decreases only slightly during the progress of metal conversion.

The effect of temperature is less simple. The action of hydrogen on massive uranium becomes noticeable when the temperature of the metal reaches about 100 to 150° C. and proceeds most rapidly in the vicinity of 225° C., as indicated in Fig. 1. However, the purity of the hydrogen and the state of the metal affect the time necessary for conversion at any temperature. A small percentage of oxygen in the hydrogen delays the start of reaction, particularly at temperatures below 200° C. A slight oxide on the metal also causes a delay so that a temperature above 225° C. may give the highest average rate. On the other hand, finely divided uranium, made by the decomposition of a previously made hydride and presumably completely free of oxide film, combines with hydrogen slowly at −80° C. and briskly at room temperature. Figure 1 was obtained with purified hydrogen acting on uranium wire.

Pressure of hydrogen also affects the rate of reaction. Higher pressures produce higher rates, but as the reaction is strongly exothermic, the higher rates may cause the temperature to rise above the allowable limit for the apparatus. A less serious consequence of the rise of temperature is a reduction of the rate of reaction in accordance with Fig. 1. Provided that the apparatus does not fail, an equilibrium will eventually establish itself between the increase in temperature and the decrease in rate of reaction. Adjustment of the flow of hydrogen to the reaction vessel is an effective means of controlling the rate of reaction and the consequent rise of temperature.

If the hydrogen pressure falls too low, conversion may be undesirably slow; an excessively low pressure will reverse the direction of the reaction. The pressure at which the reaction

*Contribution No. 142 from the Institute for Atomic Research and the Department of Chemistry. The work was performed in the Ames Laboratory of the Atomic Energy Commission.

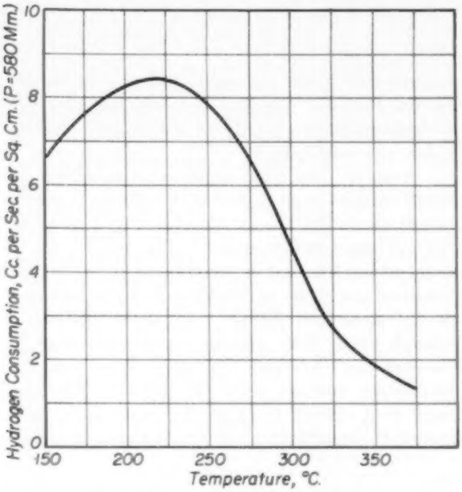
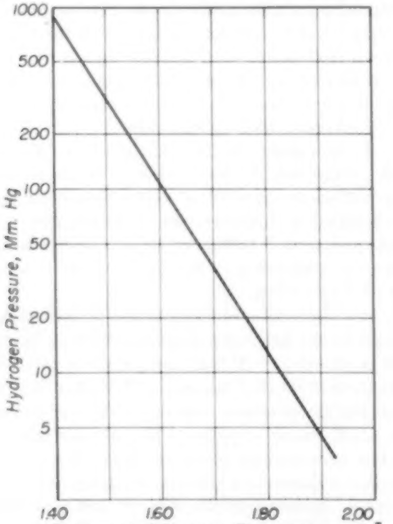


Fig. 1 — The Change in Rate of Reaction of Hydrogen With Uranium as Temperature Increases. Rates are for purified hydrogen reacting with uranium wire

does not proceed in either direction is shown as a function of temperature in the conventional way in Fig. 2. In Fig. 3, a section of this graph has been replotted with degrees centigrade as the principal variable. Obviously, if the pressure-temperature point representing any condition of the reacting system lies above the curve,

Fig. 2 — Change in the Pressure of Hydrogen Over Uranium Hydride as the Temperature Is Varied. This graph shows the conventional plot of dissociation pressure against the reciprocal of the absolute temperature on semilogarithm paper



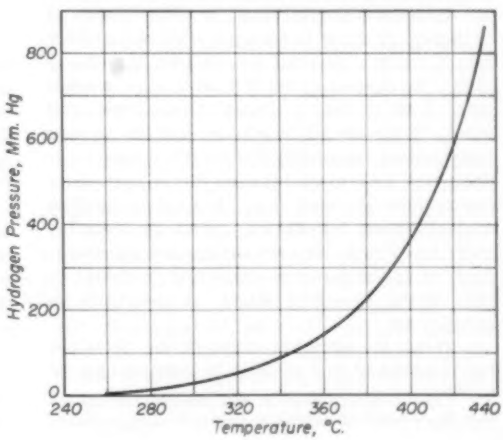
hydride will form, whereas, if the representative point lies below the curve, the hydride will decompose (metal will be formed).

The second stage of the process, the decomposition of uranium hydride to uranium powder, requires the removal of hydrogen under conditions suggested by Fig. 3. In general, decomposition will be more rapid as the pressure of hydrogen is reduced further below the equilibrium value. As indicated in Fig. 3, uranium hydride can be decomposed at atmospheric pressure if the temperature is raised above 430° C.* although the resulting metal is less satisfactory for some purposes. During the decomposition stage, an increased amount of energy must be supplied to the furnace to compensate for the heat absorbed in the dissociation of uranium hydride. It is this absorption of heat that causes the sharp drop in temperature as dissociation begins when pumping is started.

Having set down some of the basic facts, we may now consider equipment and procedure. For the small amounts of powdered uranium occasionally prepared for laboratory use, perhaps 100 to 250 g., conventional laboratory apparatus such as that illustrated in Fig. 4 is satisfactory. An ordinary carbon combustion furnace is a suitable heating unit. A suitable container for the charge can be made by sealing one end of a Pyrex glass tube of the proper size to slide in the furnace. The other end of the tube may be provided with a ground, tapered joint to receive a cap that connects to the

*Some data indicate that this value may be as much as 5° C. too high.

Fig. 3 — Dissociation Pressure of Uranium Hydride Increases With Increasing Temperature



remaining apparatus. As a precaution against loosening of the cap if the pressure of hydrogen should rise above atmospheric value, the two portions of the joint may be tied together with string or wire. Connections to the vacuum pump and the hydrogen supply are made in the customary manner. As the hydrogen should be as free as possible from oxygen and moisture, it should be led through a tube containing copper at about 600° C. and a tower or tube containing a drying agent such as $Mg(ClO_4)_2$. An extremely effective purification of hydrogen is obtained if the gas is led over uranium turnings or powder at a temperature of 600 or 700° C.

Stopcocks should be provided for cutting off the connections to the pump and to the supply of hydrogen. In particular, a stopcock immediately beyond the ground joint is desirable so that the container of powdered metal can be closed off from the air when it is disconnected from the remainder of the apparatus. With this arrangement, the container may be used to store the powder temporarily or may be attached to another piece of apparatus.

Because lathe turnings or other forms of uranium are likely to have an oxide scale which makes reaction proceed less rapidly, the charge should be cleaned in dilute* nitric acid, washed with distilled water, rinsed in acetone, and dried. Time should be allowed for the acetone to evaporate completely before the turnings are disturbed, as a spark between pieces may cause the acetone to catch fire. A good precaution against trouble is to have a helium- or argon-fed cover ready to be set over any ignited substance. As soon as the turnings are dry they should be put in the container which should then be pumped out.

When the pressure of air in the container has diminished to 5 or 10μ, the system may be flushed with hydrogen and power may be turned on the furnace. During heating, the pressure of hydrogen customarily is maintained slightly above one atmosphere.

Usually, the total time for conversion of small charges is decreased if the charge is maintained above 225° C., indicated in Fig. 1 as being the optimum temperature. The reason for a reduced total period of conversion at the higher temperature is the shortening of the incubation period described below. In most instances, enough oxide film remains on the uranium to prevent the entering hydrogen from making immediate contact with the metal. The gas must first diffuse through the oxide layer and form UH_3 in sufficient amount to cause the layer to crumble off, after which the reaction will proceed in a normal manner. If the charge is in small pieces, the time for diffusion at lower temperatures is a large fraction of the total time of conversion. For this reason, the charge usually is maintained in the range of 250 to 300° C. At this temperature a 100-g. charge can be converted to hydride in about a half hour. The reader should note that the temperature of the charge may be higher than the temperature of the furnace because of the exothermic heat of reaction.

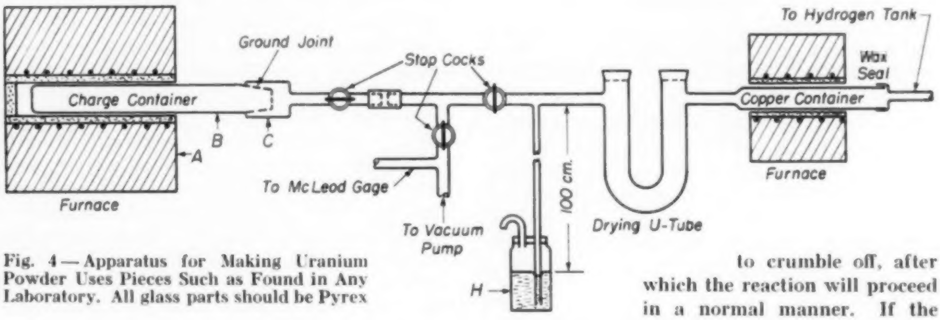


Fig. 4 — Apparatus for Making Uranium Powder Uses Pieces Such as Found in Any Laboratory. All glass parts should be Pyrex

In operation at any temperature, an estimate of the rate of conversion is obtained from observation of the rate at which hydrogen must be admitted to maintain an approximately constant pressure. When hydrogen is no longer taken up, the reaction has reached its practical end of conversion.

Decomposition of the hydride proceeds most rapidly if the hydrogen is pumped off as rapidly as it is given up. A high temperature is advantageous in this step because the higher existing dissociation pressure means that hydrogen comes off more rapidly. The temperature is limited, however, by the tendency of the reduced powder to sinter to particles of aggregate. This tendency becomes noticeable at 300 to 350° C. but still higher temperatures usually are

*The concentration of acid should not exceed 50% by volume if explosive action is to be avoided.

employed because mild jarring of the container suffices to break up the aggregates into individual grains even when the hydride has been decomposed at 400° C. or a little higher. An added advantage of the higher temperature is that the product is less pyrophoric than powder produced at a lower temperature. Under the conditions outlined, a 100-g. quantity of uranium hydride can be deprived of its hydrogen in about one hour.

The method of production outlined above has the merit that the strongly pyrophoric UH_3 is not exposed to the atmosphere at any time. When necessary, uranium hydride at room temperature can be handled safely under nitrogen or carbon dioxide. Carbon dioxide is a convenient atmosphere since it can be obtained from a piece of dry ice and is quite safe if the temperature of the hydride is not above 100° C. At 200° C. an observable reaction between hydride and gas sets in and once the reaction becomes energetic it is difficult to stop. The reduced metal is less pyrophoric than the hydride but should be handled with precautions like those indicated for the hydride. Calcined lime smothers the ignited material sufficiently to prevent fire spreading to other objects, but the uranium usually reverts to the oxide once action has started.

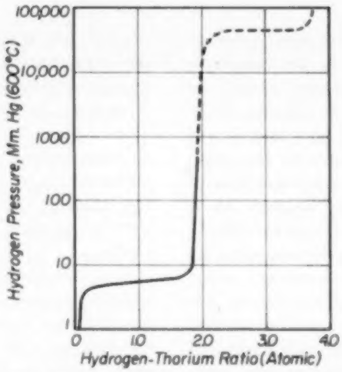


Fig. 5 — Dissociation Pressure of Thorium Hydrides at 600° C. Left portion of curve redrawn from Fig. 2 in report CC 2722; right portion is based on equation given in the same report

PRODUCTION OF POWDERED THORIUM

Thorium reacts with hydrogen to form two hydrides — one with the formula ThH_2 and another of undetermined proportions, ThH_X, but, apparently, either $ThH_{3.75}$ or ThH_4. The hydrogen-thorium ratio seems to be sensitive to the conditions of formation. A consequence of the existence of two compounds is a pressure-composition curve with two levels as in Fig. 5, which shows the isothermal curve for 600° C. The left portion of this curve has been redrawn from Fig. 2 (in CC 2722) and corresponds to the reaction $Th + H_2 = ThH_2$. The right portion is an approximation based on calculations from the equation

$$P_{(mm)} = \frac{-4220}{T} + 9.50$$

corresponding to the reaction $ThH_2 + (x/2 - 1)H_2 = ThH_X$.

From an examination of this figure, one notes immediately that the dissociation pressure of the higher hydride is very much greater than that of the lower hydride at the same temperature. Evidently, the formation of ThH_2 may proceed under lower pressures than are required for the preparation of ThH_X at the same temperature, or, considerably higher temperatures may be employed in preparing ThH_2 than can be used in forming ThH_X under an approximately fixed pressure.

These facts suggest the desirability of dividing both the formation and decomposition steps of making powdered thorium into two parts. This procedure is as shown below:

1. Formation of dihydride, ThH_2, between 600 and 650° C.
2. Formation of the higher hydride at temperatures not above 320° C.
3. Decomposition of the higher hydride at temperatures up to 500° C. under a pressure of one atmosphere of hydrogen.
4. Decomposition of the lower hydride at 700° C. at low pressure.

Since the procedure is more complicated, more exact details are given for the production of thorium than were furnished for making uranium metal powder.

Seamless, plain carbon steel tubing is suitable for a container for thorium, although if the operator desires to take advantage of higher pressures and temperatures, a stainless steel tube would be preferable. For small lots, a fused silica tube may be used. A steel tube used in some production runs was 4⅜ in. in diameter by 26 in. long and could hold 10 lb. of coarse thorium turnings with ample room for expansion of the charge during the formation of the hydride. One end of the tube was closed by a steel plate welded on; the other was cooled by a spiral of copper tubing through which water ran. Closure of the cooled end was by a water-cooled plate bearing a small pipe for connection to the remainder of the apparatus. The tube was provided with ears so that the cap could be fastened to it by means of clamps. The joint between tube and cap was made tight by means of a rubber gasket.

A large furnace similar to the small one

shown in Fig. 4, for making uranium powder, is a suitable source of heat. A thermocouple for measurement of temperature should be placed in contact with the steel container. Connections to suitable vacuum pumps and to the hydrogen supply must be provided in the manner described for uranium. For evacuation of the system, a diffusion pump backed by a mechanical pump, such as a Hypervac 23, is desirable. The pressure of hydrogen may be determined by an ordinary manometer, but a McLeod gage or other device for measuring low pressure also should be included in the system. Suitable means for purifying the hydrogen should be included, although experimental runs have been made with hydrogen as it came from the tank.

Turnings or chips are the most desirable form of charge as they react rapidly. However, blocks up to 4 in. in diameter (the cropped heads of 4-in. diameter ingots) have been used successfully. After the charge has been put in place and the cap fastened on the tube, the system should be sealed vacuum-tight. With the equipment described above, pumping for 20 min. should reduce the pressure to about 1μ.

After tests have shown the system to be free from leaks, power may be turned on the furnace and the temperature brought up between 350 and 400° C., which is about the minimum temperature at which hydrogen reacts with thorium. While the furnace is being brought up to temperature or at the beginning of the reaction period, hydrogen may be alternately admitted and pumped out as a means of sweeping out the products of degassing. Except during pumping, the pressure of hydrogen may be maintained slightly above one atmosphere.

If the charge consists of chips or turnings, the exothermic heat suffices to maintain the temperature in the converting range. If the temperature shows evidence of rising above 700° C., the hydrogen supply should be throttled down or diluted with helium or argon. Too much dependence should not be placed on the indication of the thermocouple at this time as the reaction may spread out from a single point while the remainder of the charge experiences little effect. Visual observation of the outside of the tube will show whether the charge is becoming excessively hot in one region. If the charge consists of large pieces, exothermic heat will not maintain the operating temperature and some energy must be supplied to the heating element.

The operator can determine the conversion rate roughly by watching the rate of decrease of pressure when the supply of hydrogen is cut off temporarily. As the composition of the charge approaches the proportion ThH_2 the consumption of hydrogen becomes increasingly slow. This behavior indicates, in Fig. 5, that a point representing atmospheric pressure and composition of the charge, which has been moving steadily to the right, is approaching the vertical portion of the curve and is unable to cross it.

When the absorption of hydrogen at atmospheric pressure has ceased, the temperature of the furnace may be allowed to decrease until consumption of hydrogen again becomes energetic which it does about 320° C.* Absorption of hydrogen continues at temperatures as low as 100° C. and below, but the action is most rapid about 250° C. When the consumption of hydrogen stops again, the operation is complete.

The lower hydride of thorium forms with little disintegration of the charge although a swelling, corresponding to the decreased density, is observed. During the formation of the higher hydride, grains of hydride begin to fall off and the pieces of the charge lose their individual outlines. Jarring of the container during or after the reaction period will cause the pieces to break up noticeably but much of the charge remains in relatively coarse particles about the size to pass a 30-mesh screen. For a 10-lb. charge of turnings, the time for conversion to the higher hydride under atmospheric pressure is a little more than 6 hr., of which about 2 are spent in the reaction of thorium to ThH_2 and 4 are required for production of the higher hydride after the temperature of the furnace has diminished to the reacting value.

Decomposition of the higher hydride can be performed under atmospheric pressure easily if one increases the temperature of the furnace gradually to 500° C. When no more hydrogen comes off, the temperature of the furnace may be increased again to about 700° C. and decomposition of the dihydride started under pumping. Evacuation should be continued until the pressure of hydrogen is below 1 mm. of mercury. This condition corresponds to a very low percentage of hydride. The pumping period for a 10-lb. charge of chips is about 4 hr., and for the whole operation of hydrogen removal is about 6 hr. For a 22-lb. charge of large blocks, the pumping period lasts about 8 hr. under the conditions outlined.

*Since the dissociation pressure of the higher hydride at 350° C. is only 500 mm., one would expect that the reaction would start above this temperature.

After reduction of the hydride is complete, the container should be cooled and flooded with argon or helium. When the cover is removed, a piece of dry ice may be dropped into the container to provide an atmosphere of CO_2. The product as taken from the container is coarsely granular but contains some larger pieces. Most of the material will pass a 30-mesh screen and a little of it will pass a 100-mesh screen. If desirable, the entire product may be ground to pass a 100-mesh screen, but as the metal is pyrophoric, the possibility of ignition is present unless the work is done under CO_2 or an inert atmosphere. The product can be handled in air at ordinary temperature without ignition. If stored, it should be kept in a closed container.

In addition to the practice of grinding the final product, two other methods are available for the preparation of fine powder. The particle size can be decreased by repeated cycles of formation and decomposition of the hydride. However, this method is time consuming. An alternative procedure is the grinding of the charge during the hydride stage. Steel balls are placed in the reaction tube along with the charge. Then, after the hydrides have been formed, the reaction tube may be detached temporarily from the remainder of the apparatus and used as a ball mill for grinding the charge under a hydrogen atmosphere. The hydride is quite brittle and breaks up rapidly into a very fine powder. This finely divided hydride can then be decomposed as described above. If the decomposition is carried out at 700° C. or below, very little sintering takes place. The contamination of the thorium powder by iron picked up from the steel container is slight; it certainly is less than 50 parts per million. Thorium powder reduced from the ball-milled hydride contained 175 parts per million of iron.

ACKNOWLEDGMENTS

Except for the details of the method for making powdered thorium, which are based on the experience of the senior author, most of this review is a summary of reports in the files of the Ames Laboratory of the Atomic Energy Commission. Figure 1 was taken from LA Report 37. Virtually all other data are from work done at the Ames Laboratory at various times since the beginning of 1943. The investigations were made under the direction of F. H. Spedding and H. A. Wilhelm by N. C. Baenziger, T. A. Butler, A. H. Daane, I. B. Johns, O. Johnson, A. S. Newton, R. W. Nottorf, J. E. Powell, R. E. Rundle, J. C. Warf, and A. S. Wilson.

The authors are also indebted to A. H. Daane and D. Ahmann for additional information for the making of uranium powder.

Properties of Uranium, Thorium, and Their Hydrides

PROPERTY	UNIT	URANIUM		UH_3	THORIUM	ThH_2	ThH_x
		α	γ				
True density	g./cc.	19.0	—	10.9	11.7	9.20	8.33
Density as powder	g./cc.	—	—	3.4	2.7	—	—
Cell structure		orthorhombic[1]	b. c. cubic[2]	cubic[3]	f. c. cubic[4]	b. c. tetr.[5]	cubic[6]
Dimensions of unit cell	Å	2.852 5.865 4.945	3.467	6.63	5.08	4.09 5.02	9.09
Metal atoms per unit cell		4	2	8	4	2	16
Space group		D_{2h}^{17} — Cm cm	O_h^9 — Im 3m	O_h^3, O^2 or T_d^4	O_h^5 — Fm 3m	D_{4h}^{17} — ?	T_d^6 — $I\bar{4}3d$
Heat of formation				−30,500		−35,000	−19,000
Dissociation equation	$P_{(mm)}$ =			$\frac{-4500}{T} + 9.23$		$\frac{-7700}{T} + 9.54$	$\frac{-4220}{T} + 9.50$

1. "The Crystalline Structure of Uranium", by C. W. Jacob and B. E. Warren, *Journal*, American Chemical Society, Vol. 59, 1937, p. 2588 to 2591.

2. A. S. Wilson and R. E. Rundle, Atomic Energy Commission AEC D-2046 (to be published in National Nuclear Energy Series).

3. "The Structure of Uranium Hydride and Deuteride", by R. E. Rundle, *Journal*, American Chemical Society, Vol. 69, 1947, p. 1719 to 1723.

4. "Eine neue Anordnung für röntgenkristallographische Untersuchungen von Kristallpulver", by Helge Bohlin, *Annalen der Physik*, Ser. 4, Vol. 61, 1920, p. 421 to 439.

5. R. E. Rundle, A. S. Wilson, R. W. Nottorf and R. Ræuchle, Atomic Energy Commission AEC D-2120 (to be published in *Acta Crystallographica*).

6. "A Physical Study of the Thorium-Hydrogen System", by R. W. Nottorf, A. S. Wilson, R. E. Rundle, A. S. Newton and J. E. Powell, CC 2722, March 8, 1945.

Caterpillar's Experience With Boron Steels

As a measure to conserve critical chromium, nickel and molybdenum, boron steels have been recommended for those applications in which the conventional triple-alloy steels are selected primarily according to their hardenability properties. The H-band data for certain boron steels made in considerable tonnage match very satisfactorily the H-bands of higher-alloy conventional alloy steels they have replaced. Also, there is available a considerable amount of information that recommends the use of these steels on the basis of properties determined by laboratory investigation; however, there is very little published information that concerns their behavior under production and service conditions. The nine years of experience accumulated by Caterpillar Tractor Co., Peoria, Ill., in the processing and service studies of some of these steels provides a commentary that will be of interest to potential users of the new series — and that means practically everybody because the supply situation is becoming tighter.

Caterpillar's experience with boron steels dates back to the early days of World War II when boron was first considered as a possible substitute for some of the chromium, nickel and molybdenum content of the "high-potency" alloy steels. Subsequent developments led to the adoption of the NE Steels (National Emergency Steels) which made such good use of the "tramp" alloy in remelting scrap that concentrated interest by Government and industry in the more economical boron steels came to an end. However, on the basis of the results that Caterpillar, and others, had obtained from these early investigations, Caterpillar continued working with trial heats of boron-treated steels until sufficient evidence was obtained to order mill heats in substantial tonnages. The steels they concentrated on and have been using since that time are 86B45* as a replacement for 2345 and 4340, and 14B35 (formerly designated as 10B35) for 3140 and 4140. Not a single failure of a part, despite many years of rigorous service, has been attributed to the use of boron-treated steels.

According to F. F. Vaughn (who has assisted chief metallurgist Glen C. Riegel in the Caterpillar boron steel program) a factor that has assured successful use of these steels is that material is selected on the basis of meeting specifications for minimum hardenability and notch toughness. By taking tests from locations which represent extremes within the mill heat — that is, the bottom of the first ingot and the top of the last ingot that are to be used for a given specification — the danger of putting into production material that is unsuitable for the part is eliminated to a very great extent. The tests

*See Data Sheet, p. 80-B, in last month's *Metal Progress*.

Engraving at Head of the Article Represents Caterpillar's Famous Equipment for Progressive Heat Treatment of Bar Stock for High-Strength Bolts, Capscrews, Studs and Similar Screw Machine Parts. The four lines of induction equipment handle boron steel 14B35 in stride

performed are for Jominy end-quench hardenability, impact and tensile strengths and hardness. In addition, spectrographic analysis is made for boron.

Parts made of 86B45 are axle shafts, wheel spindles and steering knuckle arms. The 14B35 grade is used for bolts, capscrews and studs under ½ in. and over ⅞ in. in diameter; intermediate sizes are of fine-grained 1038 which is selected on a hardenability basis to meet the optimum requirements of the specification for these parts. Sizes under ½ in. are oil quenched; the water quench is used only for diameters over ⅞ in. All of these parts require thorough hardening to withstand the high stresses imposed on them during service. Final structure of the metal for all parts is tempered martensite. Sizes, which range from under ½ in. for the bolts to 5 in. for axles, together with the specifications, give a good indication of what can be expected of boron steels.

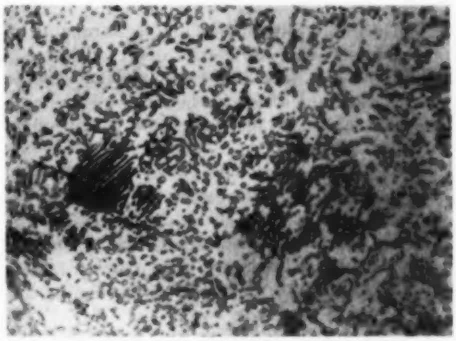
Typical specifications for these items run as follows: The 1¼ to 5-in. steering knuckle arms, wheel spindles and axles of 86B45 call for a minimum Jominy hardenability of Rockwell C-50 at a distance of 10/16 in.; the 14B35 bolts require a minimum hardenability of Rockwell C-40 at 4/16 in., 145,000 psi. tensile strength, an Izod impact strength of 36 ft-lb. at −20° F. and 42 ft-lb. at 75° F., using a 0.010-in. radius "V" notch; ⅞ to 1⅜-in. studs of the 14B35 grade steel require an 80,000-psi. minimum yield strength, a notch toughness (Izod impact, "V" notch) of 40 ft-lb. at −20° F. and 50 ft-lb. at 75° F., and hardness of C-20 to 28.

Caterpillar has used approximately 20,000 to 25,000 tons of 86B45 and 30,000 to 35,000 tons of 14B35 during the past nine years. The total steel tonnage used annually by this sprawling plant of 128 acres of modern buildings employing 22,000 production workers approximates a half million tons. It may be of interest to note that Caterpillar's several suppliers of the boron steels have been using Grainal 79 as the boron addition agent.

Mr. Vaughn states they have had no difficulty in machining, forging or heat treating the boron steels. In fact, the advantages offered in machining and heat treating that were discovered as soon as the steels were thoroughly investigated were deemed sufficiently important by the company to put up with the early tribulations in getting mills to accept these "special" analysis steels. However, some effort must be made to obtain a structure that is best suited for a given machining method. For example, if turning involves the greatest part of the machining time and hobbing or broaching are secondary, then the structure should be relatively soft so that turning can be done in minimum time, although some compromise must be made to have sufficient hardness to prevent serious tearing of metal during hobbing or broaching.

In the annealed and as-rolled condition, boron-treated steel is softer than conventional alloy steels of comparable hardenability, thereby giving tools and dies a longer life. This increased tool life has been reported by firms making bolts for Caterpillar and some of this information was quoted by Porter R. Wray in the article "Boron Steels for Constructional Parts and for Carburizing" which appeared in *Metal Progress* for July 1951. In that article the production of 8640 and 1035+B cold headed bolts and capscrews is compared to show the number of pieces that were run before it was necessary to regrind tools and dies, the 1035+B steel giving as much as a 2 to 1 gain over the 8640. Machining time for 86B45 axles has been reduced 25 to 30%, annealing time being shortened also.

The remarks made by Mr. Riegel on April 9 of this year at the Chicago meeting of the Oil



Annealed Structure of 86B45 for Best Machinability, Obtained in a Special Continuous Annealing Furnace. Picral etch, 1500 ×

ANNEALING CYCLE

1. Heat to 1600° F.
2. Cool to less than 800° F. (accelerated controlled atmosphere)
3. Heat to 1380° F.
4. Cool to 1210° F. (accelerated controlled atmosphere)
5. Hold at 1210° F. for 3 hr.
6. Cool to less than 600° F.
7. Discharge

Field Supply group briefly summarize some of the important practices observed by his company:

"Normalized or air cooled sections of shafts, such as the bevel pinion and shaft or the spur pinion and shaft, on which only the gear end is liquid quenched, might give trouble by being low in hardness — and hence in strength — on the air cooled section. This could result in twisting off in torsion. Therefore, to obtain any value from the boron alloying agent, the part must be liquid quenched and tempered.

"Intensifying the hardenability of low-carbon steel, such as that in the core of carburized gears or similar parts of thin section, might result in a serious hazard from overall brittleness. Thus, in a thin-tooth section, the stress conditions may reverse in hardening, due to the formation of martensite in the core subsequent to the hardening of the case and cause the tooth to be easily broken off by shock. Instead of having the case in compression and the core in tension, the tooth then is as brittle as if it were made of 'through-hardened' steel.

Boron Steel 86B45 Has Been Used for Several Years by Caterpillar Tractor Co. for Highly Stressed Axle Shafts, Spindles, and Similar Heavy Section Parts of 3 to 6-In. Diameter

"Some sacrifice of hardness of carburized cases quenched from the carburizing temperature of 1700° F. or higher has been observed in the boron-treated steels. Quenching from temperatures only slightly above the upper transformation range or by reheating for hardening has been found satisfactory.

"Generally speaking, our experience has shown that in using boron-treated steels, we have had to reduce the carbon content of the steel it replaced by as much as three to five points. There is one disadvantage in using the lean alloy boron steels to replace the common constructional grades of alloy steel, namely the higher temperatures necessary for retaining ferrite in solution during quenching. This produces more distortion and unless more energetic means are used for removing the heat properly, there may result a poor product and high scrap loss."

Two continuous cycle annealing furnaces are used for the axles and the other parts made of 86B45. The first heating zone brings the metal to normalizing temperature from which it is cooled by a recirculating atmosphere; the second heating zone brings the metal to the austenizing temperature from which it is cooled as rapidily as possible, *without undercooling*, to the isothermal decomposition temperature. Electric induction heaters are used for progressive hardening and tempering stud stock in bar lengths.

Carburized 94B20 series has been used experimentally for transmission gears and final drive pinions with very satisfactory results. Inspections were made at 3000-hr. intervals up to 10,000 hr. and in some cases even to as much as 20,000 hr. of service under the various conditions that Caterpillar tractors, bulldozers and scrapers meet in practically all parts of the world. On the strength of this early experience, a contemplated change to the future use of this boron steel is not expected to present any problems in processing, carburizing, or service performance.

Radioactive Tracers Reveal Friction and Wear of Metals

By J. T. Burwell* and C. O. Strang†
Massachusetts Institute of Technology
Cambridge

Although frictional phenomena have always been a part of everyday life, the basic knowledge of the mechanism underlying friction is very incomplete. Prior to 1920, friction was thought to be due solely to the mechanical interlocking of small irregularities or roughnesses on the rubbing surfaces. The force of friction was considered to be the tangential force necessary to slide the protuberances of one surface up the slopes of those on the other surface against the action of the normal force or load pressing the two surfaces together. On this basis the coefficient of friction, or ratio of tangential force to normal force, can be shown to be equal to the tangent of the mean angle of inclination of the surface irregularities.

While this hypothesis served to explain the so-called "laws of friction" observed by Amontons and Coulomb, it failed to account for the energy expended in the friction process. It can be seen that unless some other mechanism is responsible for friction, sliding should proceed without the expenditure of energy, for the work to slide or lift one surface up the slope to the top of the protuberances of the other should be recovered upon sliding down the reverse slope. Then, too, careful measurements showed that improving the smoothness of the surfaces did not reduce greatly the friction coefficient as would be the case if this theory were correct.

The modern theory of friction, due to Hardy, Tomlinson, Bowden, Holm and others, postulates that the major part of frictional resistance is caused by molecular adhesion in those regions where the surfaces are in intimate contact and the resulting deformation of these regions on sliding. The finest of surfaces, be they ground, lapped, or polished, are rough by molecular standards and when two surfaces are pressed into contact, the applied load is carried entirely by a few high points which flow plastically until they are large enough to support the load. The sum of these local areas is very small and constitutes only a small fraction of the nominal area over which the surfaces appear to be in contact. It is argued that, because of the high plastic flow pressures and intimate contact of the two surfaces at these points, a form of pressure weld or adhesion occurs over these local areas, even at room temperature. The force of friction is the summation of the forces required to shear all of these minute welds and so permit sliding.

If the welds are weak because of contamination of the surfaces by oxide layers or greasy substances, or because the metals of the two surfaces exhibit little affinity for each other, they will usually break on the surface of original adhesion and little surface damage will occur. If, on the other hand, the metals are clean and mutually soluble in the solid state, the welds that are formed may be expected to be strong, their strength being further increased by local strain hardening from deformation and rubbing so that they are stronger than the materials of one or both surfaces.

Therefore, the welds should shear to one side in the bulk of the weaker metal and a minute particle of the softer metal should be found adhering to the harder metal. It should be kept in mind that this is not the gross welding or visible galling observed on machine parts which have failed from inadequate lubrication but occurs instead on an extremely minute scale, far below the resolving power of the optical microscope. However, detection of the weld metal transferred from one surface to another during sliding is important in verifying and extending the adhesion theory of friction. Toward this end, a radioactive tracer method has been developed and used at the Massachusetts Institute of Technology Lubrication Laboratory.

RADIOACTIVE TRACER TECHNIQUE

The radioactive tracer method for detecting metal transfer or "microwelding" is extremely simple in concept. It consists of making one of the two rubbing surfaces radioactive, rubbing

*Now with Horizons, Inc., Cleveland.
†Now with Kiekhaefer Corp., Cedarburg, Wis.

them together under controlled conditions, and then examining the second surface for evidence of radioactivity. The first experiments (conducted in 1944 by Sakmann, Burwell and Irvine) demonstrated the feasibility of the method and showed that minute amounts of material from one surface were indeed transferred and adhered firmly to the second surface.

Experiments carried out before the recent war were difficult in practice because the active specimens had to be prepared either by irradiation in a cyclotron or by adding an active isotope to a melt of the specimen metal. The first method was poor from the quantitative standpoint as the resulting specific activity (disintegration rate per unit volume of metal) of the metal, and hence its calibration, in terms of volume of transferred material, varied greatly with distance from the surface, the penetration of the bombarding beam being very low. The melt method was acceptable in this respect since it gave a uniform activity throughout the specimen but was very laborious in the preparation of finished specimens.

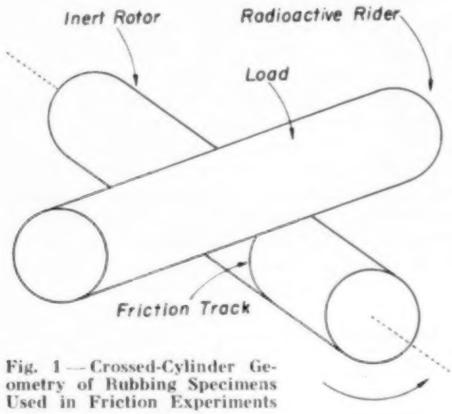


Fig. 1 — Crossed-Cylinder Geometry of Rubbing Specimens Used in Friction Experiments

With the advent of neutron piles, however, material may readily be activated in a uniform manner by exposing the finished specimen to an atmosphere of slow neutrons, such as found in the uranium pile at the Clinton National Laboratory at Oak Ridge. The choice of isotopes is limited to those which can be produced by bombardment with slow neutrons. However, most metals commonly used for bearing or rubbing surfaces are suitable for this method of preparation although the sensitivity of their detection varies markedly. For instance, copper and chromium can be detected in extremely minute amounts while iron is much less suitable for such experimentation.

Detection Methods — After carrying out the friction or wear experiment with the active and inert specimens, the latter is examined for evidence of transferred metal from the active specimen. This can be done in two ways. One is with the Geiger counter which gives a quantitative measure of the amount of active metal welded to the inert surface but yields little information as to its distribution. The other means of detection is by placing a sheet of X-ray film firmly in contact with the surface to be studied and allowing the radioactive particles adhering to the inert surface to take their own picture. This shows the distribution of transferred material and supplements the information obtained by counting methods. In the absence of a counter, comparative quantitative data may be obtained from the density of the photographs or autoradiographs as they are called, providing that care is taken in the control of exposure and development times.

Using both of these detection techniques, some examples are given in the subsequent discussion of the type of friction problems to which the tracer method can be applied and the light that it can throw on the nature of friction.

Effect of Lubricant — To study the effect of using a lubricant between sliding surfaces, a series of friction tests was conducted using a laboratory friction apparatus. This consisted of two cylindrical steel specimens pressed together with their axes at right angles to make contact at one point as shown in Fig. 1. The radioactive specimen was held stationary while the inert specimen rotated about its own axis so that the friction track consisted of a band around the rotating member.

Figure 2 is an autoradiograph of the tracks left by two such tests on a single rotating specimen in the absence of a lubricant. Since the film was wrapped around the cylindrical specimen to make the exposure, each track appears as a straight line when the film is unrolled. In this case the inert, rotating specimen was a superfinished casehardened steel and the radioactive cylinder was a hard-chromium plated steel. It will be noted that the transferred metal is not smeared or in a solid track but appears in discrete spots as though there had been individual welds. Very little surface change on this specimen was visible to the eye. This test was conducted with clean, dry surfaces.

Figure 3 shows the results from a similar experiment wherein two tracks were made using white mineral oil as a lubricant (tracks A and

thus confirming the hypothesis that friction is due, in part at least, to the formation of minute welds. On the basis of results such as those in Table I, it would appear that the quantity of metal transfer occurring between two surfaces is a measure of the tendency of these metals toward large-scale galling and seizure, such as one observes on failure of a machine part. Hence, the tracer technique may provide a very rapid means for evaluating the galling resistance of materials for a given application, and thereby reveal their wear.*

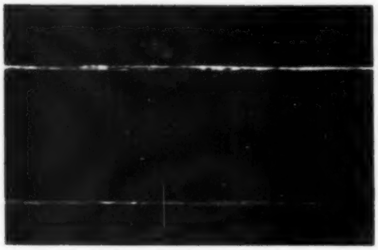


Fig. 2 — Autoradiograph of Radioactive Chromium Transferred to Casehardened Steel Surface During the Dry Sliding Friction Tests

Fig. 3 (Right) — Autoradiograph of Chromium Transferred to Casehardened Steel When White Mineral Oil Is Used as a Lubricant (A and C) and When Oleic Acid Is Used (B and D)

C). It can be seen that the track is much less heavy and also that it is considerably less spotty. Two other tracks were made with oleic acid, but despite the presence of this very good boundary lubricant, some transfer or welding took place (tracks B and D). The tracks made with oleic acid do not appear very clearly in the reproduction but are quite visible on the original negative. A quantitative measure of the transfer was obtained with the Geiger counter and is shown in Table I for the same test conditions.

Other investigators have shown by a similar type of experiment that the reduction in amount of material transferred with a good lubricant was due entirely to a reduction in the size of each weld while the number of welds remained the same. They further showed that transfer would also take place in the absence of sliding — merely by pressing the two surfaces together.

From these and many other experiments of a similar type, it has been found that this transfer of metal from one surface to another always takes place no matter how good the lubricant and is an intrinsic part of the friction process,

Effect of Surface Hardness — In order to study the effect of hardness on the microwelding, measurements of transfer were made with a series of nitralloy specimens of graduated hardness. The geometry of crossed cylindrical specimens was used for the friction tests and the quantity of metal transferred from active to inert specimen was measured with a Geiger counter. These tests were carried out with clean specimens in the absence of a lubricant. A single radioactive specimen was used as the stationary member and the hardness of the rotating or inert specimen was varied. Results of this set of tests are given in Fig. 4 and it will be seen that the quantity of transfer to the moving specimen increases continuously with the hardness of the moving specimen. It is interesting to note that the curve shows no discontinuity at the point where the hardness of the radioactive stationary member becomes less than that of the moving specimen, from which we must conclude that to some extent the transfer occurs in both directions simultaneously.

Similar results were obtained with radioactive specimens of hard chromium plate and moving specimens of nitralloy, although the quantities of transferred metal were smaller.

Table I — Amount of Transfer From Chromium to Hardened Steel Surfaces

Lubricant Used	Coefficient of Friction	Transfer, Micrograms
None	1.10	1.5 to 3.5
White Mineral Oil	0.14	0.10
Oleic Acid	0.11	0.0001 to 0.01

*Bowden and Moore have shown, by following the radioactive metal, that certain oil additives will chemically react with and remove small amounts of metal from a surface exposed to them. Conversely Clark, Gallo and Lincoln have studied the film formation on solid surfaces made by other types of oil additives with the use of a radioactive atom in the oil. As these experiments were done in the absence of rubbing, they are purely chemical problems and are only mentioned here in passing.

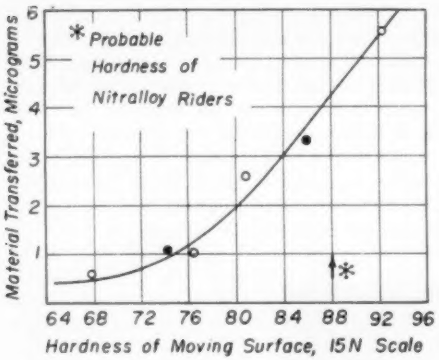


Fig. 4 — Metal Transferred From Nitralloy Riders to a Series of Moving Nitralloy Surfaces of Varying Hardness for a Given Distance and Load

This is not unexpected, for the chromium was somewhat harder, and it has also been observed that metal transfer is less when the two surfaces are dissimilar than when they are the same. All of the foregoing tests were run under the same conditions of load, sliding velocity, and sliding distance, while surface finish was carefully controlled.

The observed trend with hardness further substantiates the microwelding hypothesis of friction because with increasing hardness of the receiving member relative to the donating member of the friction pair, one would expect that the welds would be increasingly liable to break on the side of the latter, thus leaving greater amounts of material on the receiving surface. The fact that material is transferred even when the receiving surface is softer than the donating surface shows that the choice of which side of the weld will rupture on sliding is somewhat random in an individual case and only varies statistically with the relative hardness of the two.

Effect of Material Composition — While the foregoing data show that metal transfer increases smoothly with relative hardness of the receiving specimen, this holds only when the materials are similar. When widely different metals are used as the receiving surface, it is found that the effect of composition overshadows the effect of hardness. The data of Table II were obtained with a stationary radioactive specimen of cast iron rubbing on a variety of moving specimens which are arranged in order of increasing hardness in this table. It will be seen that the quantity of transfer does not follow the hardness alone but varies with the material of the moving specimen. These runs were made with white mineral oil as the lubricant and the magnitude of the amount transferred is therefore appreciably lower than was found in the study of the effect of surface hardness where no lubricant was used.

Taking the S.A.E. 1020 steel as a reference, the S.A.E. 1119 picked up less material even though it was harder. This was probably due to the presence of the sulphide stringers which would be expected to break up the occurrence of the welds and possibly serve also as a solid lubricant. The S.A.E. 4027 picked up more material than the 1020, as would be expected from its increased hardness. The cast iron (which had a somewhat different composition from the cast iron of the donating surface) picked up relatively less than its hardness would predict, presumably due to the graphite in it. This is borne out by the reduced friction.

The carburized steels showed the most unexpected results. These four steels were the same S.A.E. 1020, 1119, and 4027 steels which were used in the softened state plus a fourth steel. The pickup in all cases lay between 0.10 and 0.15 micrograms. In other words, carburizing these steels sharply reduced the pickup — despite the increase in hardness. This may be due to the high concentration of carbides in the surface which would not be expected to weld easily to the iron in the cast iron donating surface. Hence carburizing, in addition to reducing wear of the surface being carburized through increasing its hardness, also reduces the pickup of material from the softer surface against which it is rubbing and, therefore, reduces the incipient galling.

METAL TRANSFER IN MACHINE ELEMENTS

In addition to the laboratory results described above, the radioactive technique also lends itself to the investigation of the mode of action of

Table II — Metal Transfer From Lubricated Cast Iron to Various Receiving Surfaces

Moving Surface	Hardness, 15-N Scale	Coefficient of Friction	Transfer, Micrograms
S.A.E. 1020	46	0.12	0.50
S.A.E. 1119	57	0.12	0.21
S.A.E. 4027	60	0.12	0.88
Cast Iron	67	0.10	0.29
Average of 4 carburized steels	90	0.15	0.13

Load, 7 lb. Speed, 1.73 ft. per min. Distance of travel, 104 ft. Lubricant, white mineral oil

sliding parts in actual machines. As an example, the action of a piston ring in the cylinder of an internal combustion engine can be studied. The top ring is activated by irradiation in the neutron pile and inserted in the engine in customary fashion, the engine run for a period of time under specified conditions, and torn down for inspection. The walls of the cylinder were scrubbed clean of loose residue, and a sheet of film is slipped into the cylinder and pressed firmly against the wall by inflating a rubber bladder in the cylinder.

The resulting pattern of the metal transferred to the wall by the piston ring, shown in Fig. 5, bears a close resemblance to the commonly observed distribution of wear along a cylinder — that is, the transfer is heaviest near the top of the stroke, diminishes toward the middle, and increases again near the bottom position. This parallelism between transfer and wear suggests that transfer to the other surface may be an intermediate step in the formation of a loose wear particle. Similar tests (reported elsewhere) run under a wide variety of conditions have been a step toward a better understanding of the action of piston rings.

Fig. 5 — Section of Autoradiograph Showing Piston Ring Metal Transferred to Cylinder Wall During Operation of Internal Combustion Engine, Heaviest Wear Being at Top of Stroke (Top of Picture)

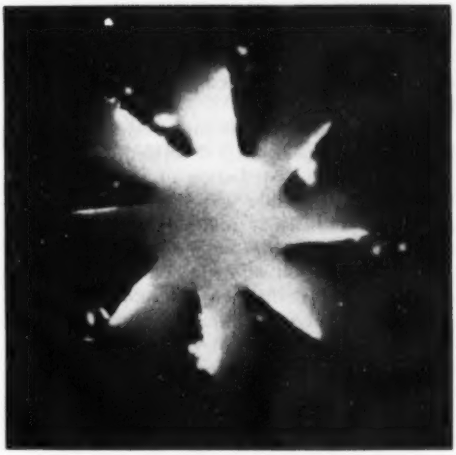


Fig. 6 — Autoradiograph of End Milling Cutter After Machining Radioactive Steel Showing Build-Up of Metal at Cutting Edges. Radiograph enlarged 2.5 ×

Another application to practical mechanical operations is a study of the built-up edge which forms on metal cutting tools. In one instance, the metal to be cut was made radioactive and then machined with a standard cutting tool. Autoradiographic examination of the tool tip yields evidence as to the nature of the built-up edge when various cutting fluids are used. Figure 6 is a rather striking autoradiograph of the cutting end of a new eight-flute end mill which had been used to cut the end of a radioactive steel specimen using carbon tetrachloride as the cutting fluid. It will be seen from the white patches along the cutting edges that a minute built-up edge is present even though nothing was visible under the optical microscope.

MEASUREMENT OF WEAR

A somewhat different philosophy of the tracer technique application is not to investigate the fundamental mechanism of the friction and wear process as has been described so far but to use it as a tool for the quantitative measurement of wear under standard conditions. As such, it may have considerable advantage in certain

instances over the conventional methods of wear measurement employed heretofore. In this category is the work of Pinotti, Hull & McLaughlin on the wear of piston rings in an internal combustion engine.

They used a piston ring made radioactive in the manner previously described, but instead of studying the distribution of material transferred to the cylinder wall, they measured the amount of radioactive material collected in the crankcase oil as the run progressed by taking samples of the oil at definite intervals. This method had two distinct advantages over the conventional method of chemical analysis of oil samples for iron. First it was extremely rapid, readings being obtained in a matter of minutes after the sample was taken from the crankcase. Second, by supplementing it with chemical analysis of the oil for total iron, the amount of worn iron in the oil contributed separately by the ring and by the cylinder and other parts of the engine could be determined. This is obviously valuable in attempting to choose better wearing piston ring materials.

Others have recently shown that it is also possible to measure small amounts of wear by a procedure somewhat the inverse of the above. A very thin layer of the surface is impregnated with radioactive atoms, in this case the fission fragments from a material being bombarded by neutrons. The decrease in the activity of this layer as it wears off is studied. The method is limited to a given range of thicknesses, in their case from 10^{-5} to 10^{-4} in., but is quite sensitive in this range.

While this article does not attempt to cover exhaustively the use of radioactive tracer methods in studies of friction and wear, it is hoped that it may suggest new experiments to other workers and so lead to further increase in our knowledge of these complex surface phenomena.

Acknowledgment — Most of these studies were made possible by a research grant from the Chrysler Corp. That portion of the work dealing with nitrided surfaces was sponsored by the National Advisory Committee for Aeronautics. The neutron irradiation of the specimens referred to in this article was carried out by the Clinton Laboratory of the Monsanto Chemical Co. under authorization of the U. S. Atomic Energy Commission. The authors also acknowledge their indebtedness to the many investigators whose published reports on this subject were referred to during this study.

Quick Patina on Copper, Brass or Nickel Alloys

WEBSTER defines patina as *(a)* a film formed on copper and bronze by exposure or by treatment with acids, etc.; a fine natural patina has artistic value. *(b)* A surface mellowing or softening, as in color, with age or use.

Everyone is familiar with the beautiful green coloration seen on many roofs throughout the countryside where atmospheric conditions are conducive to its formation. Such patina also forms on statuary — as, for instance, the Statue of Liberty. Many architects and owners are partial to such color effects and would be glad to obtain copper for roofing which had been colored in the mill, or would specify that the copper roof is to be colored after it is in place, if a good rapid process were available.

Many art objects, vases, and bowls of copper, brass, bronze or other copper alloys may readily be colored and the artificial patina will be fairly long-lived. Age-old customs are burying such objects in the barnyard manure heap or soaking them with urine.

The chemical reactions responsible for the natural patina are involved, and quite an extensive literature can be found regarding the subject. Natural patina seems to form most readily on copper, brass, bronze and other copper alloys along the seacoast where the metal meets a salt atmosphere and a minimum of sulphur or sulphur compounds. Copper which has taken on its natural patina at Atlantic City, for example, might, if transferred to the atmosphere prevalent in an industrial area contaminated with sulphur fumes, turn black due to the formation of copper sulphide. As a matter of fact, it has been observed that a new

copper roof installed in a large city will often first turn a dark or blackish color and then, after a few years, gradually take on its green patina.

As an illustration within the writer's personal observation, a church close to the Harlem River in New York City had a beautiful copper steeple which had developed the natural color. Due to damage by lightning it became necessary to repair one side of the steeple. New copper sheets were installed which, within two years, formed an unsightly blackish section. It required an additional 14 years of exposure for the patched section to arrive at the point where it was difficult to distinguish from the rest of the roof. Copper's affinity for sulphur at first prevailed against the oxidizing effects of the atmosphere but the sulphur compounds formed were ultimately converted to the beautiful green.

It is the writer's opinion, based on the examination of many exposed installations and samples, that all patina, whether natural or artificially formed, will ultimately assume a color or shade that is determined and controlled by the atmosphere to which it is exposed. Dust, fume and chemical nature of the atmosphere are the major influences.

Water Pipe — Copper or brass water pipe has long been the favorite of builders and owners of substantial homes. In recent years its popularity has increased vastly with the advent of flexible, thin walled, seamless tubing and easily soldered field joints — all of which cuts the labor cost of installation quite markedly. Potable water in these pipes also causes a patina to form, an essential factor in the corrosion resistance of the metallic system.

By William G. Schneider
Consulting Engineer
Milwaukee

In those communities where the water supply has a low pH (is on the acid side) an installation of copper tubing or brass pipe may result in temporary discoloration of the bathtub or basin. This is especially true where a faucet is allowed to drip. Soon, however, the pipe will of its own accord form its natural protective coating. This coating, once formed on the inner surface of the pipe or tube, will then protect that installation from further corrosion and no further trouble from discoloration should be experienced.

Haase, in Germany, devoted considerable effort to developing a method of coating the inside of pipe previous to its installation. The subject has had much attention, especially from investigators abroad where water conditions are not as well controlled as in this country. Discoloration from copper or brass water systems in this country is the exception rather than the rule, and is usually caused by stray currents or by water-softening systems, improperly installed or operated. Copper and brass, when properly installed, have exceedingly high resistance to corrosion when handling normal water supplies.

Several processes have also been developed for artificially producing the green patina and some patents have been issued. Such processes require considerable manipulation and equipment, and are difficult and inconvenient to use on a copper roof in place.

QUICK PATINA

Obviously there would be many advantages and much time might be saved if the copper, brass or bronze could be so treated that a patina would be formed before the metal is installed in service, especially in roof, piping, gutters or leaders. For ornaments the process to be described seems ideal. As previously stated, this patina will protect the underlying metal and will, depending upon the local atmospheric or water conditions, quickly change to the stable coating which would be formed under normal conditions. If, for instance, atmospheric conditions are such that a pleasing coloration will not form but that the metal will ultimately turn black, then this artificial patina will also turn black and be of no use.

It is suggested that a solution containing 1 lb. per gal. of commercial cupric nitrate dissolved in water be used for brass, commercial bronze or other copper alloys where there is an appreciable zinc content. For copper or its low-zinc alloys a solution containing 0.75 lb. of commercial cupric nitrate plus 0.25 lb. of zinc nitrate in 1 gal. of water should be used.

A test of these solutions may readily be made. The metal sheet as it comes from the mill (without further cleaning) is heated to 230° F. (275° max.). In the laboratory a thin asbestos pad can be placed over a gas burner and the copper sample put on the pad. It can be checked for temperature much as a housewife checks an iron; when the metal sizzles under a wet finger it is right! The solution is then brushed or swabbed on.

It is essential that the temperature be high enough so the metal will sizzle when the solution is applied, and further that the metal be

maintained at this temperature while the solution is being applied; otherwise, the results will not be uniform on a piece that is not uniformly heated. If the temperature is too high a black, dirty color will result. However, if this occurs the swabbing should be continued and as the temperature falls the green patina color will develop. The sample may be given several coats of solution while still on the hot plate.

As soon as the sample has taken on the greenish color it may be removed from the heat and washed with water. The coating will be hard and will not rub off on the fingers.

With a little practice very beautiful results may be obtained. Sheets measuring 24 x 36 in. have been handled in the laboratory with excellent results.

The temperature has been given as from 230 to 275° F. merely as a guide. It should be high enough for coloration, but overheating should be avoided so annealing effects are kept at a minimum.

If the metal has a coating of oil or is dirty, it is not necessary to clean it, as such adherents help to produce unusual effects.

In practice, large sheets would be sprayed as they issued from a heating furnace, using several nozzles. It would be necessary to gage the heat so that the solution does not quench the metal below the point at which the patina color is formed. Tubing can be heated with an arrangement such as is used on the Snead annealer and the solution can be fed to the inside of the tube by another smaller pipe having perforations.

Addition of zinc nitrate to the solution is not essential for copper; excellent results have been obtained when using cupric nitrate alone. Commercial cupric nitrate was found to give better results than the technical grade.

After the formation of the patina color the sample may be washed in a solution of 4 oz. of sodium hydroxide to the gallon of water. A blue color will then result, the depth of blue depending upon the length of time the sample is left in the solution. If the sodium hydroxide solution is too strong, results will be poor; if too weak, it will take too long a time to produce results. With a 4-oz. solution the time required is about 15 min.

Patina has been satisfactorily formed by the foregoing means on nickel and monel as well as copper and copper alloys. However, the manipulation of these metals necessitates somewhat greater care, because they tend to overheat, resulting in the formation of the black discoloration.

Samples exposed to an atmosphere such as prevails in Washington, D. C., yielded good results over a period of three years. Samples exposed to salt air at the seacoast had a tendency to fade but the natural patina quickly re-formed.

It is recommended that anyone interested in using the process for other than ornamental purposes (indoor exposure) try variations of the solutions and temperatures and then conduct proper exposure tests. An important point to bear in mind is that no patina is permanent in its original state for conditions other than those under which it is formed.

The patina formed by the foregoing method acts as a stop-gap to corrosive action in the time between the erection of the metal and the conversion of its surface to the patina stable under the conditions under which it must serve. In this transition period — sometimes as long as several years — the coloration is much more uniform and pleasing than when similar metal is erected with the ordinary finish given to mill products.

The Throne of Dagobert Provides an Excellent Example of the Durability of Patina. This antique bronze chair (preserved at Bibliotèque Nationale in Paris) dates back to the 12th Century

Correspondence

Age Hardenable High-Nickel Alloys

CORVALLIS, ORE.

In the April issue of *Metal Progress* W. A. Mudge reports (p. 529) the age hardening properties of various high-nickel alloys. His summary, as a statement of facts, is of value for users of the materials. However, the research metallurgists would like to have some information as to the causes of the age hardening of these alloys, at least as far as it can be explained by their chemical analysis.

As quoted in the table of nominal properties (p. 530) the analyses approach or exceed 100% for all the alloys except one. The alloying elements might to some extent explain the structural hardening of "K" Monel, "KR" Monel, "S" Monel and Duranickel (which contain enough aluminum or silicon) or of Inconel "X" (which has enough titanium) for solution treatments, but this reason cannot be given for the aging of Permanickel. The titanium present in this alloy (0.4%) is low and it is probably tied up with the 0.25% carbon, showing as inclusions of carbide in the microscope, so that this element has to be ruled out as a cause for age hardenability. The total of the analysis quoted comes to 99.63%. It would be interesting to know what constitutes the balance. Perhaps a figure for magnesium content of these alloys would give some clues.

W. J. KROLL
Consultant

Passivity of Type 304

CONSHOHOCKEN, PA.

While engaged in a plant investigation, the writer had occasion to run corrosion tests on three heats of Type 304 stainless steel (18-8) in a hot (140 to 180° F.) 15% (by volume) aqueous solution of sulphuric acid containing about 1.25% sodium chloride. In the course of these tests, some curious phenomena were observed which the writer suspects may be new:

1. Corrosion rates on specimens from two heats supplied by the same vendor were greatly reduced (inhibited) in the above solution in contrast to the corrosion rates shown by the same specimens in a hot, salt-free sulphuric acid solution of identical concentration. This was true for sensitized as well as for annealed specimens. These specimens became black during exposure to the salt-free acid, and tended to remain so in the acid-salt solution. Curiously, annealed specimens from a third Type 304 heat of unknown manufacture, corroded at a rapid rate in the hot, acid-salt solution.

2. When re-immersed in hot, salt-free, 15% sulphuric acid solution after having been exposed to the hot acid-salt solution, the annealed specimens of the first and second heats were *passive* and, in contrast to their previous blackened condition, they soon became clean and bright. A sensitized specimen of one of these, likewise exposed to the hot acid-salt solution, did *not* become passive and brighten when re-immersed in the hot, salt-free, acid solution but, on the contrary, resumed approximately its original rate of dissolution. The annealed specimens from the third heat similarly did not become passive upon re-immersion in the straight acid solution.

3. Surface blackening by exposure of these stainless steels to the hot 15% sulphuric solution prior to immersion in the acid-salt mixture was apparently necessary to produce passivity upon re-immersion in the hot acid solution. One specimen, exposed to the acid-salt solution alone, showed inhibited attack but did not blacken; it failed to passivate when later immersed in straight 15% sulphuric acid.

4. Stability of the passivated surfaces of these steels in the hot acid appears to be a function of solution temperature and time of previous exposure to the hot acid-salt mixture. One specimen passivated for 1.4 hr. in the acid-salt solution remained passive for 3 hr. in the straight sulphuric solution at temperatures of 150 to 170° F.; passivity broke down at 170° F. Another remained passive for 70 hr. at temperatures averaging between 158 and 178° F. after exposure for 45 hr. to the hot acid-salt solution; passivity in this case broke down above 182° F. A third specimen passivated for 118 hr., remained unattacked by the straight sulphuric acid solution for 24 hr. at 163 to 172° F.; subsequent heating of the solution did not break down passivity until at least 208° F. was reached, above which strong attack ensued.

The writer suggests the shaky hypothesis that the passivation phenomenon exhibited by specimens from the two heats of Type 304 stainless steel is caused by the presence of

residual molybdenum in the amounts of 0.18 and 0.17%, respectively. The third heat of 18-8, which did not show the passivation phenomenon, contains no molybdenum and, although nominally of Type 304, is high in carbon (0.09%) and chromium (20.90%). On the other hand, both annealed and sensitized specimens of Type 316 (18-12 with 2½% Mo), tested under the same conditions, showed inhibited attack in the acid-salt solution but did not become passive when re-immersed in salt-free acid. Perhaps the greater corrosion resistance of Type 316 to sulphuric acid prevented the formation of enough "corrosion product" to nucleate the passivation process.

REED KNOX, JR.
Research Metallurgist
Alan Wood Steel Co.

Chemical Spot Tests for Nickel and Molybdenum

AURORA, ILL.

Considerable skill is required to identify different alloy ranges in mixed steels by spark testing even if standard reference pieces are available. We frequently use chemical spot tests for nickel and molybdenum. However, we have found that scaled and shotblasted surfaces may give erroneously high indications for these two alloying elements.

Some months ago we had forgings of 1045 steel which gave erratic results in heat treatment. These were checked for nickel on clean shotblasted surfaces and found to give strong tests. Later, the parts were rechecked on ground surfaces and gave no test. No tests were made for molybdenum on these forgings.

More recently another group of parts made of 3-in. round 4140 steel gave abnormal hardness when heat treated. Strong spot tests for nickel were obtained on shotblasted surfaces but very faint tests resulted on ground surfaces. Checking the blasting shot showed no indication of alloy.

These experiences led us to believe that nickel was being concentrated on the surface of the metal during the time the scale formed. If nickel is concentrated by scaling, perhaps molybdenum is also. We, therefore, took a slice from the 3-in. round 4140 steel and two pieces of carbon steel and subjected them to scaling tests at 1700° F. until about 0.003 in. of metal was scaled from each surface. Chemical spot tests were made for nickel and molybdenum on shotblasted and ground surfaces.

The table at the bottom of the page gives the results for these samples as well as for two 1045 forgings, together with the analyses for specified and residual alloys.

Apparently, scaling during heating for rolling, forging, and heat treating causes a preferential oxidation of iron (similar to that obtained in an openhearth furnace) while the less readily oxidizable alloys diffuse ahead of the oxidizing iron to give an alloy-rich layer just under the scale. Shotblasting removes this surface layer far more slowly than does grinding or filing.

The nickel and molybdenum which diffused from the 0.003 in. of oxidized metal is probably concentrated below the scale in a zone less than 0.001 in. deep. It must be at least this thin or such strong tests would not be obtained by scaling off only 0.003 in. of metal. Since residual nickel and molybdenum are the rule rather than the exception in steels partially made from scrap, the nickel will probably average close to one-tenth of one per cent and molybdenum a few hundredths of one per cent.

The molybdenum spot test we use will detect 0.10% but not 0.05%. Our nickel spot test has a high phosphoric acid concentration which practically eliminates the troublesome brown discoloration that frequently confuses the test when less phosphoric acid is used. A

Material	Analysis					Scaling		Chemical Spot Tests			
								Nickel		Molybdenum	
	% C	% Mn	% Ni	% Cr	% Mo	Temp. °F.	Metal Lost	Ground Surface	Blasted Surface	Ground Surface	Blasted Surface
1045 forgings	0.49	0.70	0.03	0.08	0.04	—	—	None	Strong	No test	No test
	0.50	0.73	0.10	0.04	0.05	—	—	None	Strong	No test	No test
3 in. rd., 4140	0.41	0.65	0.17	0.86	0.17	1700	0.003 in.	Faint	Strong	No test	No test
1½ in. rd., 1040	0.41	0.83	0.11	—	0.02	1700	0.003 in.	None	Moderately strong	None	Moderate
⅞ in. flat, 1022	0.19	0.88	0.09	—	0.03	1700	0.003 in.	None	Moderately strong	None	Moderate

0.20% Ni content gives a faint but readily recognized test but 0.10% will usually give no indication.

The solutions and procedures employed in the molybdenum test are:

Solution No. 1

25 ml. distilled water
20 ml. concentrated nitric acid
5 ml. 85% phosphoric acid

Solution No. 2

10% hydrochloric acid

Solution No. 3

25 g. stannous chloride
35 ml. concentrated hydrochloric acid.
Dilute to 100 ml. with distilled water, add a few pieces of metallic tin, keep in a dark bottle.

Solution No. 4

5 g. sodium thiocyanate
95 ml. distilled water

Two drops of No. 1 are placed on the cleaned metal surface, followed a short time later by one drop of No. 2. When reaction seems complete a drop of the solution is transferred with a glass stirring rod to a piece of filter paper. One drop of No. 3 is placed on the spot followed by one drop of No. 4. The formation of an orange halo around the spot indicates the presence of molybdenum. This halo is larger and deeper colored with higher molybdenum concentration of the metal tested. Except that it acts somewhat more slowly, it frequently works equally well to start with a mixture of No. 1 and 2.

Only two solutions are needed when making the test for nickel.

Solution A

400 ml. distilled water
300 ml. concentrated nitric acid
350 ml. 85% phosphoric acid

Solution B

1 g. dimethylglyoxime
60 ml. glacial acetic acid
30 ml. ammonium hydroxide
10 g. ammonium acetate

One or two drops of A are placed on the cleaned metal surface. When bubbling practically stops a small piece of filter paper is placed on the spot and a drop of B is added to the wet spot in the filter paper. Formation of a red color indicates the presence of nickel. It is faint pink for 0.20% Ni to bright red for 2.00% or more. If the spot remains white, the amount of nickel present is likely to be well under 0.20%.

ELMER H. SNYDER — Chief Metallurgist
ARTHUR H. KLEIN — Chemist
Austin-Western Co.

Etching of Titanium

URBANA, ILL.

It is difficult to develop the structure of titanium for microscopic examination. The literature advises hydrofluoric acid solutions for etching, but our experience indicates the following method of preparation is superior:

1. Manual polish through the usual 0000 papers.

2. Electrolytic polish in a solution of one part perchloric acid plus 20 parts of acetic anhydride, with a current density of 1 ampere per square centimeter; 4 min. in the bath at 40° F. or below.

3. Etch in vigorously boiling 1% sulphuric solution for 4 min.

It is imperative that the specimen be etched promptly following electrolytic polishing. Standing for a few hours passivates the surface so that an adequate etch is not produced. Since the etching reaction is essentially one of solution of the metal, it produces some slight relief, and oblique illumination often enhances the contrast between individual grains.

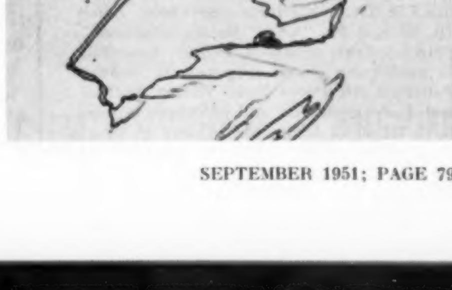
HOLLIS P. LEIGHLY
Olin Industries Fellow for Titanium Research
University of Illinois

Hysteresis, a Ghost!

PITTSBURGH, PA.

Meet Hysteresis, our watchdog on duty in 3% silicon steel. When we found him, he was blind so we gave him an eye, and now he is guarding against an influx of coercive gremlins. Pedigree? Your gauss is as good as ours (ouch!). Picral etch. × 2000.

A. G. LEE and H. S. LINK
Research Laboratory
Carnegie-Illinois Steel Corp.



Hardness Scale Selector for Steel

By E. F. Bradley
Assistant Engineering Metallurgist
Pratt & Whitney Aircraft
East Hartford, Conn.

Accurate hardness measurement is dependent upon several factors, one being that the thickness of the specimen must be great enough so that only the metal of the specimen is tested and not metal of the supporting anvil. When the penetrator makes a pronounced mark on the opposite side of the specimen ("anvil effect"), it is an indication that the true hardness test of the specimen is not registered. It is essential, therefore, that the hardness test specified or used for inspecting any part be compatible with the section thickness tested.

To provide some means of selecting suitable hardness scales, the chart shown on p. 80-B was prepared by Pratt & Whitney Aircraft division of United Aircraft Corp. It applies only to parts of nominally uniform metallographic structure (not carburized or decarburized) and of nominally uniform hardness throughout. Other factors such as necessary width, degree of surface refinement and contour of surface (that is, plane or curved) have not been taken into account, it being assumed that these conditions are those which are required for accurate hardness testing.

The curves are based on the depth of indentation caused by the hardness test, as calculated from information contained in "A.S.M. Metals Handbook" and "Hardness and Hardness Measurements", by S. R. Williams and formulas supplied us by Wilson Mechanical Instrument Co. Depth of indentation caused by the minor as well as the major load was determined in the Rockwell tests, since total penetration is the sum of the two. Authorities agree that steel is affected to a depth approximately ten times the actual depth of penetration, so the indentation figure for a given hardness and test was multiplied by ten to mark the minimum thickness of steel of that hardness that can accurately be tested by that method. For example, the sum of major and minor indentations for Rockwell C-30 is 0.0070 in.; $10 \times 0.0070 = 0.070$. C-30 is approximately equal to Vickers 302. Plot 0.070 against 302 (Point X).

To improve the usefulness of the chart, approximate conversion values* are given along the curves.

The use of the chart is explained on the chart itself (p. 80-B). A properly selected hardness test for a thin part or piece of stock should result in a penetration which does not produce a pronounced anvil impression on the underside of the specimen. Although this is a sign that the penetration has not been too deep for the thickness being tested, it has been observed that when a very slight mark is visible on the underside, accuracy of the reading is not affected significantly.

Actual hardness tests by the Materials Control Laboratory of Pratt & Whitney Aircraft on six months' receipts of soft steel sheet and strip of varying thicknesses verified the chart in the low range (DPH 80 to 250). Random checks on steel specimens of varying thicknesses and covering a greater range of hardness showed a very close agreement with the calculated values. The chart has been used by the materials laboratories, the design department and the inspection department of Pratt & Whitney Aircraft for about five years to select proper hardness test methods for steels and as an approximate hardness conversion chart.

*Based primarily on the joint A.S.M.-A.S.T.M.-S.A.E. hardness conversion tables (p. 98 and 99, "A.S.M. Metals Handbook", 1948 edition), modified slightly according to conversion charts prepared by Wright-Patterson Air Force Base, Wilson Mechanical Instrument Co., and information from R. H. Heyer of Armco Steel Corp.

Hardness Scales Included on Chart

Machine	Major Load	Type of Penetrator
Brinell	3000 kg.	10-mm. tungsten carbide ball
	3000 and 1000	10-mm. hard steel ball
Vickers (DPH)	50, 30, 10, 1 kg.	Diamond pyramid
Rockwell standard (10-kg. minor load)		
Scale C	150 kg.	Diamond brale
Scale A	60	Diamond brale
Scale B	100	$\frac{1}{16}$-in. steel ball
Scale F	60	$\frac{1}{16}$-in. steel ball
Rockwell superficial (3-kg. minor load)		
Scale 30N	30 kg.	Diamond brale
Scale 15N	15	Diamond brale
Scale 30T	30	$\frac{1}{16}$-in. steel ball
Scale 15T	15	$\frac{1}{16}$-in. steel ball

Hardness Scale Selector for Steel

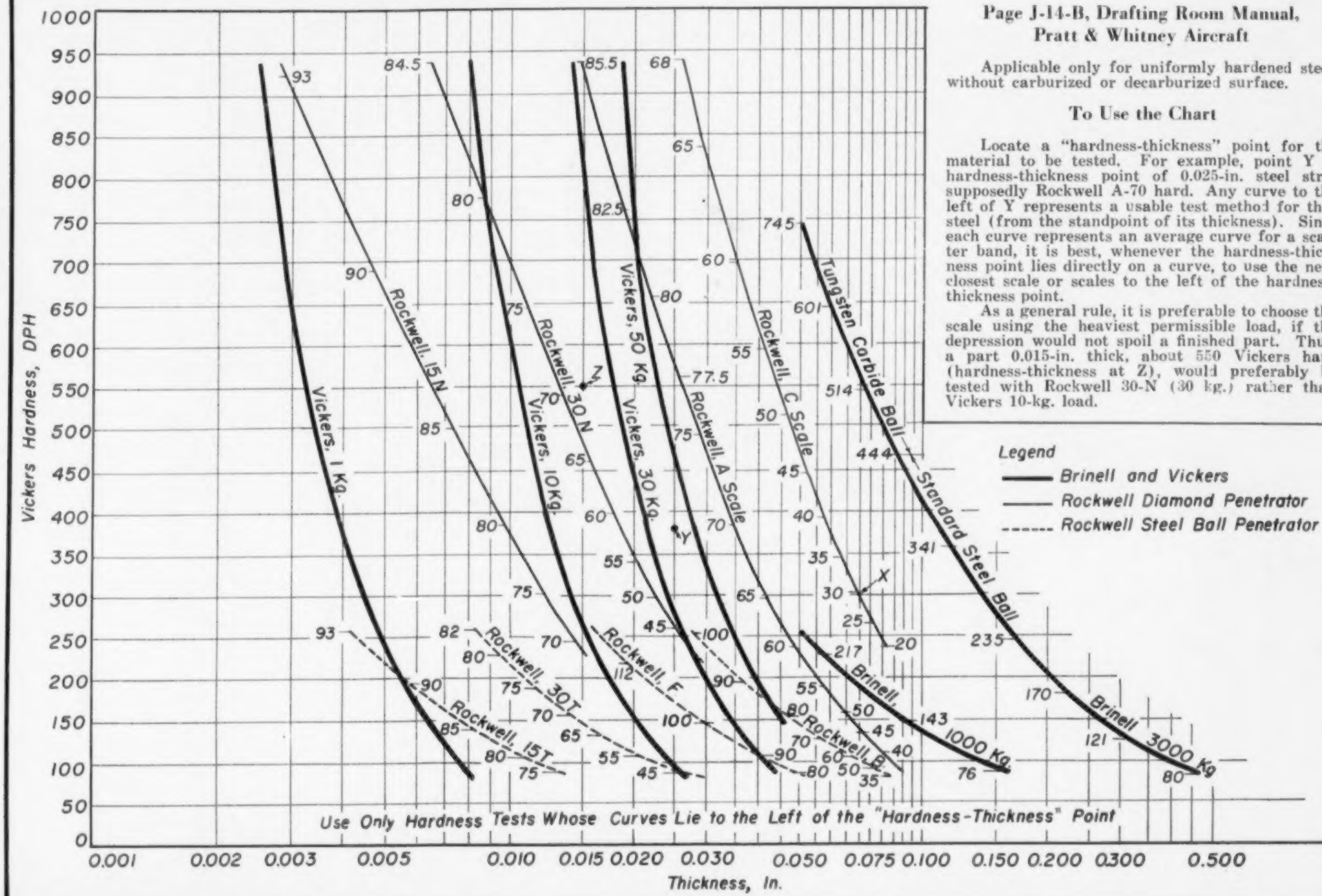
Page J-14-B, Drafting Room Manual,
Pratt & Whitney Aircraft

Applicable only for uniformly hardened steel, without carburized or decarburized surface.

To Use the Chart

Locate a "hardness-thickness" point for the material to be tested. For example, point Y is hardness-thickness point of 0.025-in. steel strip supposedly Rockwell A-70 hard. Any curve to the left of Y represents a usable test method for that steel (from the standpoint of its thickness). Since each curve represents an average curve for a scatter band, it is best, whenever the hardness-thickness point lies directly on a curve, to use the next closest scale or scales to the left of the hardness-thickness point.

As a general rule, it is preferable to choose the scale using the heaviest permissible load, if the depression would not spoil a finished part. Thus, a part 0.015-in. thick, about 550 Vickers hard (hardness-thickness at Z), would preferably be tested with Rockwell 30-N (30 kg.) rather than Vickers 10-kg. load.



Rough Spot Remover.....

SHOCK ABSORBERS OF SHARON* STEEL

IRON OUT BATTLEFIELDS FOR AMBULANCES

The steel used in this shock absorber is nothing extraordinary. It is a plain carbon steel delivered in strip form to facilitate faster production methods.

What makes this steel important is the product. The armed services need ambulances that can travel the rough battlefield terrains smoothly and without mechanical failure. The heavy duty shock absorber has proved to be the best answer. To manufacture the product in the amounts needed requires great tonnages of strip steel, much of which is being supplied by Sharon Steel Corporation.

* Specialists in STAINLESS, ALLOY, COLD ROLLED and COATED Strip Steels.

SHARONSTEEL

SHARON STEEL CORPORATION

Sharon, Pennsylvania

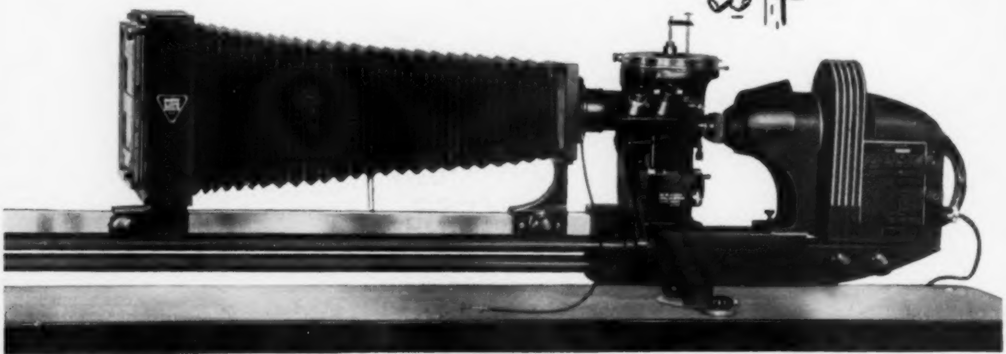
DISTRICT SALES OFFICES: CHICAGO, ILL., CINCINNATI, O., CLEVELAND, O., DAYTON, O., DETROIT, MICH., INDIANAPOLIS, IND., MILWAUKEE, WIS., NEW YORK, N. Y., PHILADELPHIA, PENNA., ROCHESTER, N. Y., LOS ANGELES, CALIF., SAN FRANCISCO, CALIF., MONTREAL, QUE., TORONTO, ONT.

For information on Titanium Developments contact Mallory-Sharon Titanium Corp., Indianapolis, 6.

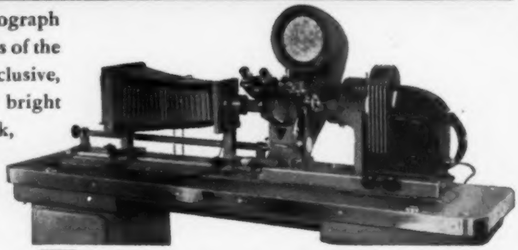
REDUCE WASTE . . .

FROM LADLE TO FINISHED PRODUCT

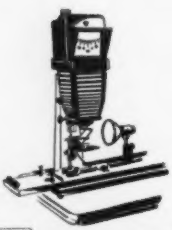
. . . in research and production . . . save materials and manpower . . . with the Bausch & Lomb complete line of metallurgical equipment



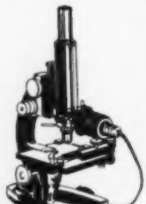
RESEARCH METALLOGRAPH—See it . . . photograph it . . . *four* ways! Four different accurate images of the same sample, for more complete identification. Exclusive, patented B&L features permit critical work with bright field, dark field or polarized light . . . with quick, easy change-over. For phase contrast work B&L accessories are simply, speedily attached. The "maximum use" instrument for visual observation and photomicrography. Catalog E-240.



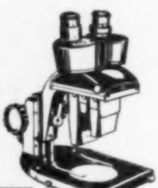
NEW! BALPHOT METALLOGRAPH—The economy of limited capacity instruments, with bright field, dark field or polarized light and phase contrast . . . and many other advantages of the highest-priced metallographs. Quick-action stage elevating device eliminates coarse adjustment. Bright, magnified screen images . . . ideal for grain size determinations and group viewing. Catalog E-232.



PHOTOMICROGRAPHIC EQUIPMENT MODEL L—With proper accessories *this one unit* provides visual microscopy, high and low power photomicrography, as well as photocopying. Catalog E-210.



CM METALLURGICAL MICROSCOPE—For examination of opaque objects, polished metal specimens, similar materials. Catalog E-223. Tri-Vert Illuminator (optional) provides bright field, dark field, or polarized light. Catalog D-108.



STEREOSCOPIC WIDE FIELD MICROSCOPES—Invaluable in preparation of polished metal specimens, study of fractures, porosity, macro-etched specimens and other low power metallurgical studies. Catalog D-15.

SEE THEM AT THE NATIONAL METAL SHOW DETROIT, OCTOBER 15-19 — SPACE 102

Write for complete information to Bausch & Lomb Optical Co., 638-9 St Paul St., Rochester 2, N. Y.

Bausch & Lomb *Metallurgical* Equipment

Strength of Pure Molybdenum at 1800 to 2400°F.

By Roger A. Long, K. C. Dike, and H. R. Bear
Lewis Flight Propulsion Laboratory
N.A.C.A., Cleveland

THE PRESENT NEED for engineering materials having satisfactory properties when over 1800° F. has caused all promising materials to be thoroughly investigated. Molybdenum is one such; it is tough, dense, refractory; it melts at or above 4750° F. However, it has never been considered suitable for use at elevated temperatures other than in a vacuum or controlled atmosphere because of its poor oxidation resistance. Coatings have recently been developed that protect molybdenum from oxidation, and this will change the outlook.

Since little information is recorded concerning its strength properties at high temperatures, an investigation was started by the National Advisory Committee for Aeronautics. The work was reported in Technical Note 2319 by the present authors, and the present article is drawn from that document.

Ductile molybdenum is now being economically fabricated by powder metallurgy methods and by arc casting. Our study was on metal fabricated by powder metallurgy as follows: Pure molybdenum powder is cold pressed into bar compacts and then sintered in a reducing atmosphere at temperatures near the melting point. Sintering is followed by hot swaging and drawing or rolling. Swaging and other reduction methods, performed hot, are supposedly below the recrystallization temperature and therefore impart beneficial cold working effects which result in high strength and ductility at room temperature.

We used metal from two sources. Metal from one source originated as "ingots" weighing 5 kg. (11 lb.) and measuring 1⅛ in. square by 24 in. long. Manufacturer's analysis showed 0.01% iron, 0.015% nonvolatiles, balance molybdenum. Eight ingots were swaged to ¼ in., ½ in., $\frac{11}{16}$ in. and 1 in. diameter, representing cross-sectional reductions of 96, 85, 70 and 38%.

Source B prepared $\frac{9}{16}$ x ⅝ x 24-in. ingots weighing a little over 3 lb. analyzing 0.005% iron, 0.003% carbon, balance molybdenum, from which rods ½ and ¼ in. diameter were swaged, representing reductions from ingot of 44 and 86% respectively.

From these rods test specimens were cut as shown in Fig. 1. The gage lengths were ground to smoothness of 5 to 16 rms. (root mean square in microinches).

Structure of Bars — Initial swaging of sintered molybdenum bars superimposed hot and cold working, resulting in complex structures. Although initial swaging is a high-temperature, manually operated forging operation with a reheat after each 10 to 15% reduction, and each reheat is at a progressively lower temperature, a limited amount of actual cold work occurs.

Continued working in the reduction of the 1-in. to the ½-in. bars greatly improved the metal's homogeneity; however, structural variables were not completely eliminated.

Figure 2 shows a typical cross section of a 1-in. bar, as swaged. Because swaging imparts greater deformations near the surface than at the center, recrystallization probably occurred near the outer part of the bar during one or more of the reheats. Further swaging broke down these reformed grains, whereas in the center the deformation was cumulative. The core is noncircular because the bar was swaged from a rectangular ingot.

An example of a strain gradient is shown along a radius at 7 o'clock. During swaging no recrystallization occurred in the central portion. The very large grains half way out indicate critical strain with limited deformation after recrystallization. The fine grains near the surface are different from those in the core, for higher magnification indicates severe fragmentation during working. Adjacent grains in the large-grained area that received similar amounts of deformation show considerable variance in strain markings under the microscope, which probably originated from prior grain orientation.

The core of this sample has the smallest grains encountered in this investigation, very similar in size to that of the ingot after sintering and before swaging. It also contains a multitude of very fine pores, their number always

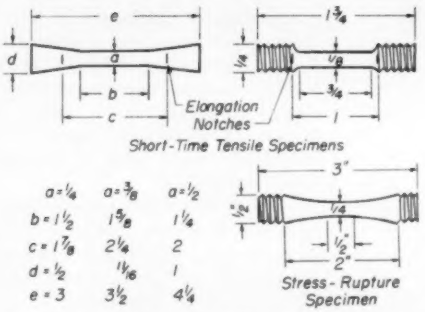


Fig. 1 — Test Specimens. Elongation marks were scribed as shown; elongation at fracture was measured after reassembling broken specimen

decreasing from the bar's center toward the circumference.

As-swaged structures of the ½-in. bars were of two general types, and neither contained a core area. One was small grained throughout, whereas the other was large grained throughout. In both types the larger grains were found near the surface. These variations of structure are believed to have originated in the size of the original particle of powder, or to have been introduced by the swaging variables.

INFLUENCE OF SPECIMEN SIZE AND LOCATION

In swaging, the metal adjacent to the surface receives more work than the metal in the center of the bar. If this imparted considerably different mechanical properties to the material in the center, the data obtained from a small tensile specimen would not be representative of the entire cross section of a larger bar.

To determine size effects, a 11/16-in. bar was chosen because it had been swaged a sufficient amount (70%) so the working effect reached the center, because specimens of smaller size could readily be cut from it, and because it recrystallized above 2400° F. (the maximum temperature of this series of tests). It had a typical structure consisting of elongated, severely strained grains, slightly more "fibrous" near the circumference of the bar, but fairly uniform in size and shape across the diameter of the bar. Figure 3 is a typical structure after testing at 2200° F. — it having been unchanged from that of the original as-swaged bar.

Tensile bars with test sections ⅛, ¼, ⅜ and ½ in. in diameter were cut from the above, representing 3, 13, 29 and 51% of the original cross section, and each size was tested at 1800, 2000, 2200 and 2400° F. Strengths varied within a range of about 3500 psi. at both room and elevated temperatures, which range is within material variations. If a difference in strength does exist from the center to the outside, it is too small to detect. Actual figures are:

Temperature	Maximum	Minimum
Room	90,550 psi.	87,680 psi.
1800° F.	33,650	32,500
2000	29,700	26,700
2200	28,500	25,650
2400	27,350	23,700

No difference in hardness was perceptible from the center to the circumference of the swaged bar. Rockwell A hardness readings varied from 53.5 to 56.0, with no definite pattern.

The effect upon ductility could not be determined from the elongation values because the ratio of length to diameter of test section varied from 2.5 to 6. Fractures were similar. Because fracture type, tensile strength, and hardness did not vary appreciably with test-section area, it is believed that ductility would also remain essentially constant.

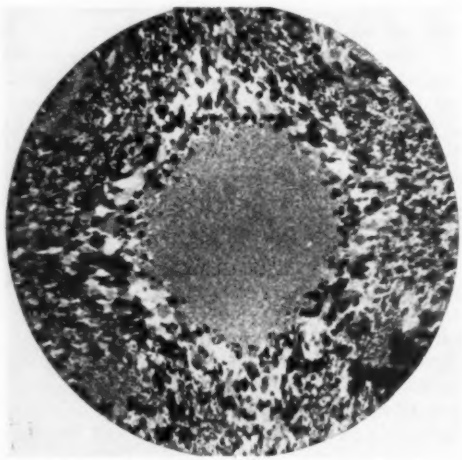


Fig. 2 — Transverse View of 1-In. Swaged Bar, Showing Flow Lines. 3×

HIGH-TEMPERATURE FURNACE

It would be well to pause for a brief description of the furnace for making such high-temperature tests as just noted. A drawing is shown in Fig. 4. All metal parts used within the heating zone of the furnace were fabricated from Inconel X. Because molybdenum oxidizes rapidly in air at 1200° F., a metal tube was placed around the tensile specimen, and a

sufficient flow of helium introduced to exclude excessive oxygen. For stress-rupture experiments a protective atmosphere of argon gas and Haynes Stellite No. 25 alloy grips proved satisfactory, since an atmosphere-protection tube was placed around the rupture specimen and recessed at both ends into the grips. This afforded constant atmosphere protection while the specimen was elongating.

Preliminary rupture testing with Inconel X grips and helium gas for a protective atmosphere proved unsatisfactory. Severe corrosion of the molybdenum occurred where it was in contact with or closely adjacent to the Inconel X in an atmosphere of helium.

Temperature of the specimen and the furnace was controlled by a thermocouple placed against the test section. Temperature was maintained to ±3° F. in the tensile tests, ±5° F. in the stress-rupture tests. Preliminary tests with four thermocouples showed a maximum variation of ±3° F. over the gage length of the test specimen.

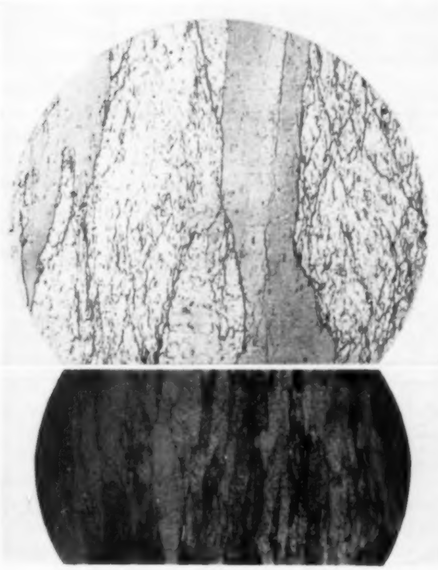


Fig. 3 — Typical Microstructure at 150 and 25 Diameters of Bar Hot Swaged 70%, After Testing at 2200° F.

It took from 1¾ to 2½ hr. to reach temperatures of respectively 1500 to 2400° F. in this furnace, and specimens were soaked for 30 min. Loading rate in the short-time tensile tests was about 2500 lb. per min. up to the yield point. Above this load, the rate of loading was increased as rapidly as possible to eliminate possible short-time stress-rupture factors and to prevent serious deformation of the gripping mechanism. Since the rate of strain beyond the yield point was not controlled, the elongation values are probably influenced by this factor.

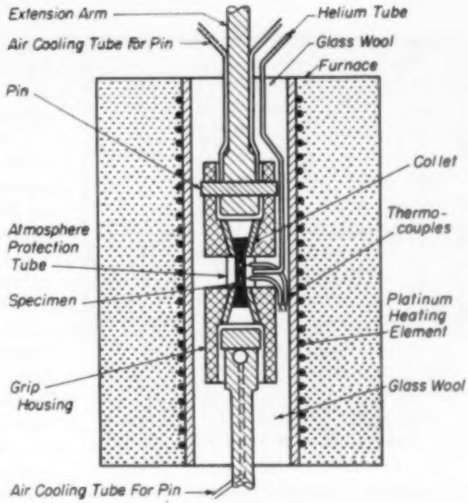


Fig. 4 — Apparatus for High-Temperature Tensile Tests. Furnace has firebrick covers on both ends. Metal parts are of Inconel X

EFFECT OF RECRYSTALLIZATION

A series of ½-in. bars from the second source (44% reduced by swaging) were machined into tapered test bars with ¼-in. diameter test section. Half were tested in the condition as received; the other half after recrystallization (heated 48 hr. at 2400° F.). Recrystallization has a detrimental effect upon the ultimate tensile strength both at room and elevated temperatures (Fig. 5). Figures alongside test points represent per cent elongation in 1.5 in. It will be noted that the recrystallized bars had practically no ductility at room temperature and broke with fracture Type 5 (see Fig. 12). As-swaged specimens tested at room temperature had fair elongation, even though the nature of the fracture was either Type 5 or 6 (Fig. 12 and 13), and they retained good values at high temperatures. Recrystallized bars had good ductility when tested at 1500 to 2000° F. with fracture Type 2 (Fig. 9), but elongation fell sharply at higher temperatures.

It appeared, therefore, that recrystallization

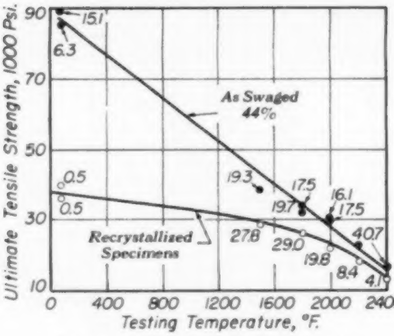


Fig. 5 — Effect of Recrystallization on the Ultimate Strength and Elongation in 1.5 In. of ¼-In. Test Specimens Pulled at High Temperature

lowered the tensile strength of molybdenum at all temperatures. Recrystallized metal was quite ductile at elevated temperatures but extremely brittle at room temperature. Recrystallized metal exhibited an intergranular fracture at room temperature; from 1500 to 2000° F. fracture was predominantly transgranular; above 2000° F. the fracture reverted to the intergranular type.

Preliminary recrystallization studies were limited to 1 hr. at temperature. The temperatures were lowered and heating periods lengthened to a maximum of 75 hr., to simulate possible high-temperature service conditions. Recrystallization was sluggish because the degrees of "effective" cold work varied considerably. (By "effective" is meant the amount of cold work that induces recrystallization which in turn affects the strength properties.)

We have two structures to examine in the larger bars: First, the core, which was converted to a well-equiaxed grain of somewhat smaller size within 24 hr. at 2800° F. Second, the large grains just outside the core did not change much in shape, area or contrast when viewed at 13 and 150 diameters, but after 24 hr. at 2800° F. the severe strain markings so prominent in the as-swaged grains almost disappeared. The absence or near absence of these markings indicated either recrystallization or stress relief. Recrystallization is always evident, microscopically, by grain re-formation; however, the large grains did not re-form, as remarked above.

In a further attempt to classify these large reheated grains, a microhardness survey was made with Knoop indenter and 2-kg. load:

	Knoop Hardness Number
Severely strained, as-swaged grains	220
Same, after 24 hr. at 2800° F.	212
Smooth, as-swaged grains	209
Same, after 24 hr. at 2800° F.	213
Recrystallized grains	184

A rather complete micrographical study of the ½-in. bars was made. These bars in longitudinal section consisted of elongated grains, almost all of which were covered with strain markings in the polished and etched section. Two varieties were noted

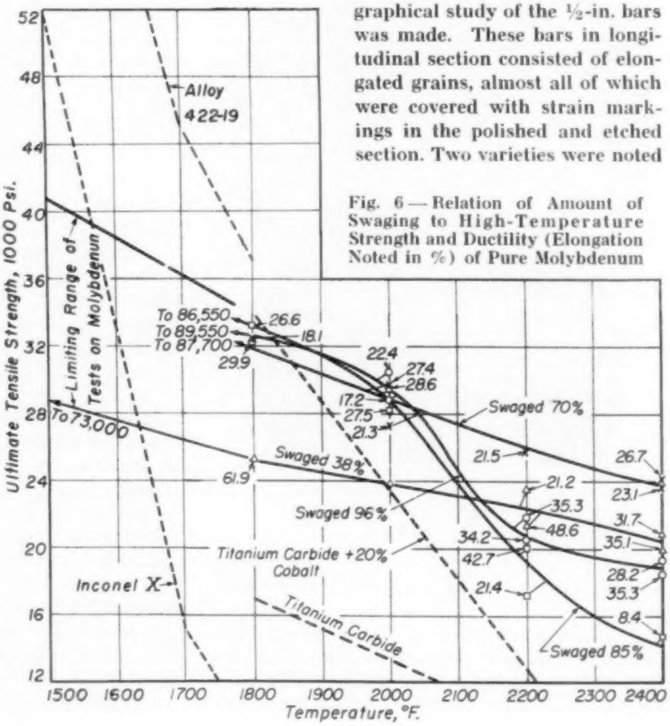


Fig. 6 — Relation of Amount of Swaging to High-Temperature Strength and Ductility (Elongation Noted in %) of Pure Molybdenum

*Lines for titanium carbide from N.A.C.A. Technical Notes No. 1911 and 1915. Inconel X (N.D.R.C. 99) is a 70-15-7 Ni-Cr-Fe with 1.0% Cb, 2.5% Ti, 0.7% Al, 0.20% Cu, 0.08% C, 0.65% Mn, 0.50% max. Si. Data are from book issued by International Nickel Co., Jan. 1949. Alloy 422-19 (N.D.R.C. 12, or Haynes Stellite No. 30) is a cobalt-base alloy with 26% Cr, 15% Ni, 6% Mo, 2.0% max. Fe, 0.40% C, 0.5% Mn and 0.5% Si. Data are from book issued by Haynes Stellite Co., 1948.

in the as-received stock; one was predominantly fine grained, the other was coarse grained. Recrystallization began in the fine-grained structure after 1 hr. at 2000° F. and was complete except near the surface of the bar after 20 hr.; the coarse-grained structure required 20 hr. at 2000° F. for beginnings of crystallization to be noted, and 20 hr. at 2200° F. was required for its completion. Recrystallization consistently began in the bar center and progressed to the surface. Under the microscope the recrystallized grain sizes are closely similar to, and also retain some of the directionalism of, the as-swaged grain sizes.

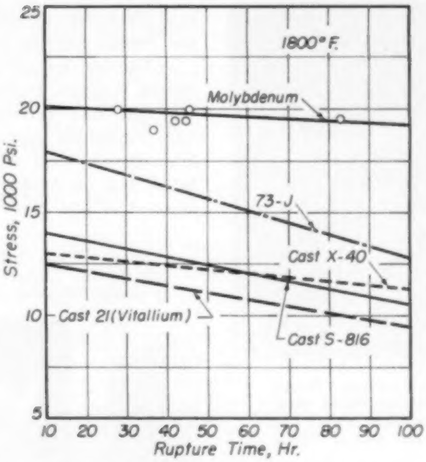


Fig. 7 — Stress-Rupture Life★ of ½-In. Wrought Molybdenum Bars at 1800° F., in Comparison With Several High Alloys. Three test results for molybdenum are for longer times: 116 hr. at 19,500 psi., and 141 hr. and 267 hr. at 19,000 psi.

Often a small but varying amount of similarly fragmented areas did not recrystallize. Because such areas appear to have been severely fragmented, they should re-form readily, but much higher temperatures and soaking times were necessary to recrystallize them.

HIGH-TEMPERATURE STRENGTH

Figure 6 gives high-temperature, short-time tensile tests on bars swaged various amounts. It will be observed that a ½-in. test piece cut from a 1-in. bar (swaged 38% from ingot size) is considerably weaker at room temperature (73,000 psi.) than others swaged more heavily. From 1800 to 2400° F. its strength was also about 20% less than the bar swaged 70%. The uniform decrease in strength with increasing temperature indicated absence of effective recrystallization. Ductility was very good at 1800° F. or higher. From 75 to 100% of the test specimen's cross section consisted of the central core of fine-grained material, similar to that shown in Fig. 2. The grains were rather uniform, a mixture of fine, strained and fragmented grains with only slight directionalism. Recrystallization studies indicated a 1-hr. recrystallization temperature of approximately 2825° F. for such material.

Figure 6 also shows that the bar swaged 70% and tested with a ⅜-in. section has a straight-line plot, and therefore also did not recrystallize during high-temperature testing. (Auxiliary studies showed its 1-hr. recrystallization temperature to be about 2500° F.) Fractures were all Type 1 (Fig. 8). Elongations, though good, were less than those recorded for the larger bar.

The bar swaged 85% and tested with a ¼-in. section showed a rapid drop in strength between 2000 and 2200° F. and a less rapid drop as 2400° F. was approached. This rapid rate of change of strength was caused by the "effective" recrystallization of the metal during testing. Its ductility was good at 1800 to 2200° F., but fell off considerably at 2400° F., where it had Type 4 fracture (Fig. 11).

While the material swaged 96% and tested in ⅛-in. section recrystallized similarly, it has uniformly high ductility (elongation). Its elongation at room temperature (26.3%) is especially noteworthy since the other three series of bars with lower reduction by swaging had practically no elongation at 70° F.

★EDITOR'S NOTE — This line is unusually flat in slope. Furthermore, it is considerably higher than the results reported by Parke on p. 95 of *Metal Progress* for July 1951.

Vitallium (Haynes Stellite Alloy 21, or N.D.R.C. 10) is cobalt base and contains 0.3% C, 1.0% Mn, 0.6% Si, 2.0% max. Fe, 27.5% Cr, 5.5% Mo and 2.5% Ni.

X-40 (Haynes Stellite Alloy 31, or N.D.R.C. 71) is also cobalt base and contains 0.5% C, 0.6% Mn, 0.7% Si, 1.5% max. Fe, 2.5% Cr, 7.5% W and 10.0% Ni.

Data for both the above are quoted from Haynes Stellite Co.'s 1948 publication "Haynes Alloys for High-Temperature Service".

73-J is an experimental casting alloy, cobalt base, containing 0.73% C, 1.0% Mn, 23.0% Cr, 6.0% Mo, 6.0% Ni and 2.0% Ta.

Cast S-816 (N.D.R.C. 76) is considerably stronger than when forged. Its chemical analysis is 0.40% C, 0.6% Mn, 0.3% Si, 20.0% Cr, 3.0% Mo, 4.0% W, 20.0% Ni, 45% Co, 4.0% Cb, balance Fe.

Data for 73-J and S-816 are quoted from Grant, Frederickson and Taylor, *The Iron Age*, March 18, 1948, p. 73.

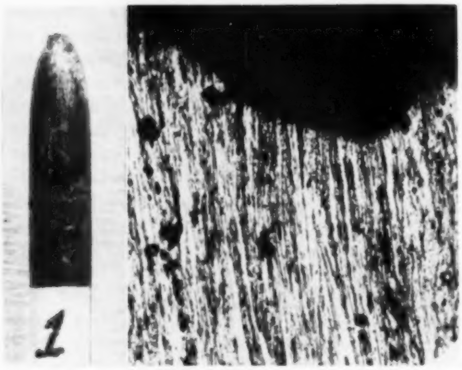


Fig. 8 — Type 1, Pin-Point Fracture; Transgranular With 70 to 90% Reduction in Area. In Fig. 8 to 13, test pieces are about full size; micros of fractured region 150 ×

This evaluation of as-swaged molybdenum indicates that swaging between 70 and 96% had a negligible effect on tensile strength at all temperatures below the recrystallization temperature. The effect of swaging upon lowering the recrystallization temperature, however, is pronounced and limits the usefulness of molybdenum at higher temperatures. Increased swaging reduction decreases room-temperature brittleness, but only if the swaging adds "effective" cold work to the metal.

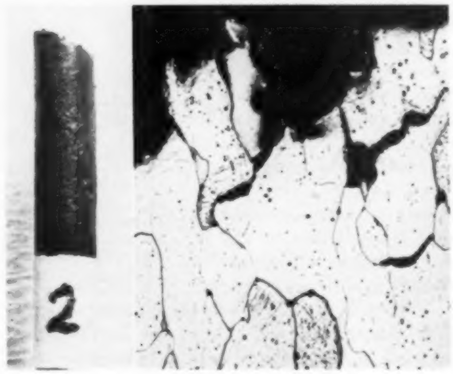
STRESS-RUPTURE IN 100 HR.

Stress-rupture tests were conducted at 1800° F. on test pieces (Fig. 1) cut from ½-in. diameter bars (swaged 85% from ingot). Results are shown in Fig. 7.

The 100-hr. recrystallization temperature of this material was in excess of 1800° F.; therefore, this variable did not affect the evaluation of as-swaged metal in the longest heating period (267 hr.).

Another lot of ½-in. bars from the same source was also tested for stress-rupture. This material was extremely heterogeneous; some bars contained hollow pipes and cold shuts. Micrograins were mixed in size, from fine to large, but no evident relation existed between amount of fine grains and rupture life.

Fig. 9 — Type 2 Fracture; Approximately 45° Shear, Either Transgranular or Intergranular With 10 to 40% Reduction in Area



The value of 19,300 psi. for the 100-hr. rupture life at 1800° F., taken from the logarithmic plot, could easily vary ±300 lb. because of the slight slope of the curve and because rupture life at any one stress could not be closely reproduced. Scattered values occurred

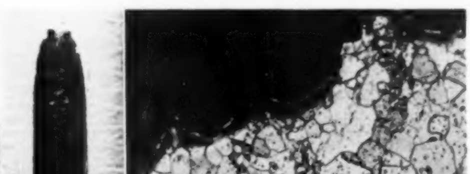


Fig. 10 — Type 3 Fracture; (Right) Honeycombed Tear; Predominantly Transgranular With 50 to 99% Reduction in Area; Left Is Torn or Honeycombed Surface Along Test Piece

at all loads for all metal evaluated. Metallographic examination did not reveal any appreciable deviation in crystal structure.

It is important to remember that the good values in Fig. 7 are for as-swaged metal only. After recrystallization, its 100-hr. strength dropped to 10,000 psi. — practically half.

DIRECTIONAL PROPERTIES OF PLATE

Rolled ¼-in. molybdenum plate is an anisotropic material, but is strong and ductile in both the transverse and longitudinal directions. At all temperatures up to 2000° F. the tensile strength in the direction transverse to rolling is somewhat greater than in the longitudinal direction; above 2000° F. the difference is within the error of testing.

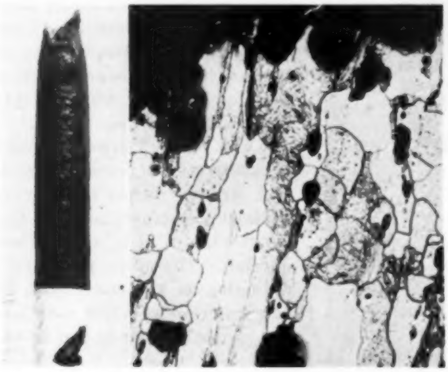


Fig. 11 — Type 4 Fracture; Tear; Predominantly Transgranular With Approximately 40% (Max.) Reduction in Area

	Strength	Elongation
Transverse at 70° F.	97,900	2.0
Longitudinal at 70° F.	87,300	2.5
Transverse at 1800° F.	40,650	14.5
Longitudinal at 1800° F.	35,200	30.1

At 2000 to 2400° F. the plate had strength about equal to the bars swaged 70% (Fig. 6) but elongations were considerably lower. The ductility in a direction normal to the surface, although not determined in this investigation, is known to be very low because of the brittle planes of weakness parallel to the surface.

Because of the rolling directionality, the tensile fractures were wedge-shaped below the recrystallization temperature, the sharp edge of the wedge being parallel to the rolling surface. Above the recrystallization temperature, the fracture changed to a rough tear type.

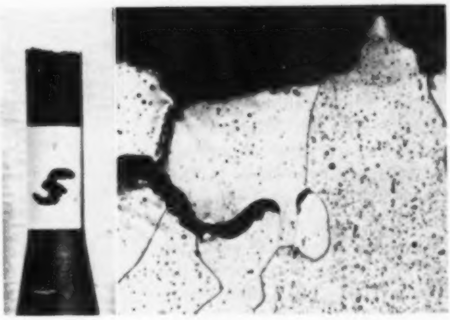


Fig. 12 — Type 5, Brittle, Transverse Fracture; Transgranular or Intergranular With Essentially No Reduction in Area

FRACTURE TYPES

As-swaged and recrystallized bar specimens exhibited six distinct types of fracture at room and elevated temperature, as shown in Fig. 8 to 13.

Molybdenum from both sources showed similar types of fracture for both as-swaged and recrystallized material. The as-swaged metal, worked sufficiently to give a fairly uniform grain structure from the circumference to the center of the bar, had a transgranular fracture with good elongation at all temperatures up to recrystallization. Material which was only partly recrystallized before or during testing had a torn fracture that was a mixture of both transgranular and intergranular failure similar to Types 3 and 4 at temperatures above 2000° F. Type 3, with the honeycombed surface, appeared to be an intergranular separation at the surface, but fracture was predominantly transgranular.

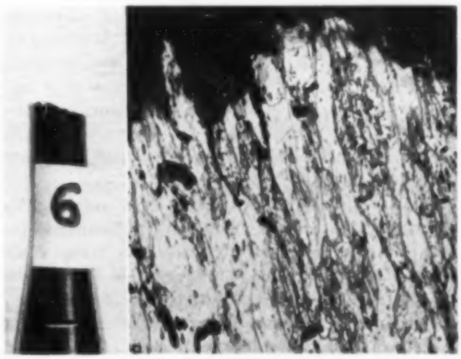
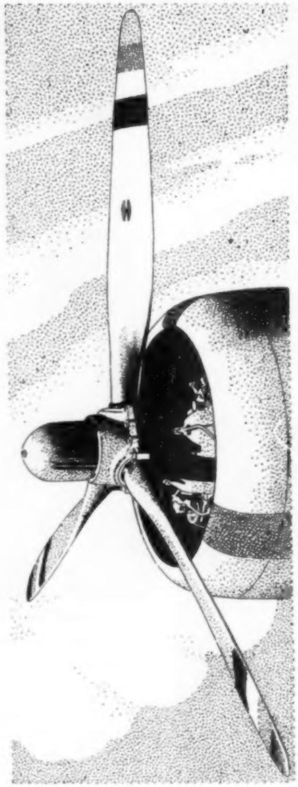


Fig. 13 — Type 6, Ductile, Transverse-Transgranular Fracture; 0 to 25% Reduction in Area

When molybdenum is fully recrystallized, fracture seeks the grain boundaries at both room temperature and at temperatures above 2000° F., resulting in an intergranular failure with low elongation. At temperatures from 1500 to 2000° F., the metal showed ductility as great as or greater than the as-swaged material. In this temperature range the fracture is predominantly transgranular. This change (reverting again to a much less ductile, intergranular fracture above 2000° F.) seems rather odd, but is borne out in part by work reported by W. P. Sykes in *Transactions* of the A.I.M.E., V. 64 (1919-1921).



RECRYSTALLIZATION

In evaluating the two manufacturers' products, a considerable variation was found in properties, particularly at elevated temperatures. Molybdenum from Source A had a fairly clean, uniform, fibrous grain structure in all the bar sizes except the 1-in. size. Fabrication was sufficiently uniform to produce metal that possessed a progressively lower recrystallization temperature and a tendency toward higher strengths with increasing amounts of swaging. Molybdenum from Source B did not show any similar systematic change, nor did it possess nearly the uniformity of structure.

The heavily swaged metal of both manufacturers had a rather uniform, fibrous grain structure, but the material from Source B had a recrystallization temperature approximately 125° F. higher than that from Source A and recrystallization occurred over a greater range of temperatures.

Material from Source B that was lightly swaged (44% reduction in area) had nonuniform grain structure, and appeared to have some porosity. However, its strength below the recrystallization temperature was 20 to 35% higher than material from Source A that had received an equivalent amount of swaging. Moreover, it had a recrystallization temperature approximately 600° F. lower, which, strangely enough, was about the same as for other metal from the same source that was swaged about twice as much.

The lightly swaged molybdenum from Source B had a grain structure that resembled recrystallized material much more closely than the fibrous, as-swaged structure found in other material. It was probably subjected to a temperature above recrystallization during the latter part of the swaging treatment for a sufficient time to cause full or partial recrystallization. Further swaging at lower temperatures might then produce some smaller fragmented grains. Possibly a large amount of previous effective swaging was lost when recrystallization occurred.

It is difficult to explain why the material still possesses excellent strength below the recrystallization temperature for the small amount of total ingot reduction. Therefore, total ingot reduction is not considered to be a criterion by which mechanical properties can be predicted.

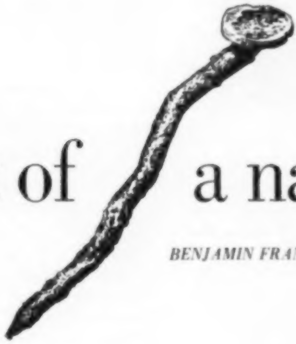
CONCLUSION

From these tests it is concluded that pure molybdenum, either as-swaged or recrystallized, has tensile properties at 1800 to 2400° F. equivalent to or higher than titanium carbide, with or without cobalt binder, or ceramic bodies. This is shown by appropriate lines in Fig. 6. At lower temperatures, up to 1500° F., molybdenum is weaker than other established alloys, like Inconel X and 422-19.

Stress-rupture properties at 1800° F., when tested in protective atmospheres, are much superior to several established alloys at that extreme temperature.

Since recrystallization has such a considerable effect on high-temperature strength properties, an extended investigation is under way at Lewis Flight Propulsion Laboratory to determine what is the cause of tardy and sluggish recrystallization in some of the test pieces we examined. If the recrystallization temperature of molybdenum could be increased, a corresponding advantage would ensue.

"For the want of a nail the shoe was lost,
For the want of a shoe the horse was lost,
For the want of a horse the rider was lost,
For the want of a rider the battle was lost,
For the want of a battle the Kingdom was lost . . .



and all for want of a nail"

BENJAMIN FRANKLIN, "Poor Richard," 1758

The fate of nations often hangs on little things. Take this rusty old nail. It symbolizes thousands of tons of worn-out machines and broken parts lying useless in our plants, factories, farms, and homes—scrap steel desperately needed today by our steel mills.

You can help make this nail, and all the other scrap you can collect, go to work again . . . in new steel for ships, tanks, and guns required for defense purposes.

So survey your plant now for every last bit of scrap. Then get it to your scrap dealer promptly. This will not only help assure the nation of the arms needed to preserve our freedom, but it will also mean more steel for your own products tomorrow.

ELECTRO METALLURGICAL COMPANY, a Division of Union Carbide and Carbon Corporation.

Personal Mention

Walter W. Edens

Unique in that he is a mechanical engineer with a master's degree in metallurgy, a research and production executive, WALTER W. EDENS ⊕, past chairman of the Milwaukee Chapter of the American Society for Metals, and current chairman of the Milwaukee Chapter of the American Foundrymen's Society, has been appointed Defense Projects Executive for Alloy Engineering and Casting Co. of Champaign, Ill. Here he will devote his full time to the Casting Potentials Project, a study for the Air Matériel Command, U.S.A.F., under general direction of **H. H. Harris** ⊕. Mr. Edens combines an academic and theoretical background in the castings and metal industries with unusual production experience, and will concentrate on devising methods whereby the foundry industry may cooperate more fruitfully with the aircraft industry. Mr. Edens received his M.S. degree from the University of Wisconsin in 1937, and spent the next ten years as chief metallurgist, foundry superintendent and technical director of Ampco Metal, Inc., of Milwaukee. Prior to his present appointment he was vice-president of Badger Brass & Aluminum Co.

Mr. Edens has been joined by **Thomas G. McNamara** ⊕, formerly chief metallurgist of Continental Aviation and Engineering Corp., Detroit, who has been appointed chief metallurgist at Alloy Engineering and Casting Co. Mr. McNamara will also spend his time on the Casting Potentials Project, studying aircraft specifications and evaluating the status of castings supplied to the aircraft industry in terms of quality.

Alfred Strasser ⊕, formerly a metallurgical engineer for the special projects department, M. W. Kellogg Co., Jersey City, N. J., has taken a position as metallurgist in the technical analysis division of Wright-Patterson Air Force Base, Dayton, Ohio.

R. H. Lambert ⊕, formerly in the welding and metals branch of the Bureau of Ships, Navy Department, Washington, D. C., has been transferred to the Philadelphia Naval Shipyard where he is shop superintendent for the production department.

Martin J. Holleran ⊕ has been named assistant manager of tool steel sales by the Carpenter Steel Co., Reading, Pa. He joined the company in 1946 and served as sales engineer out of the New York City Mill-Branch Warehouse until his recent promotion.

Philip J. Duffy ⊕, a member of Lindberg Engineering Co. for the past 12 years, is now operating as district sales and service manager for Lindberg's new office in Atlanta, Ga.

Roy F. Bourgault ⊕ has accepted a position as research associate in the Department of Metallurgy, Stevens Institute of Technology, Hoboken, N. J.

Richard L. Nyquist ⊕ has been employed by MacDermid, Inc., Waterbury, Conn., as a trainee in the sales department.

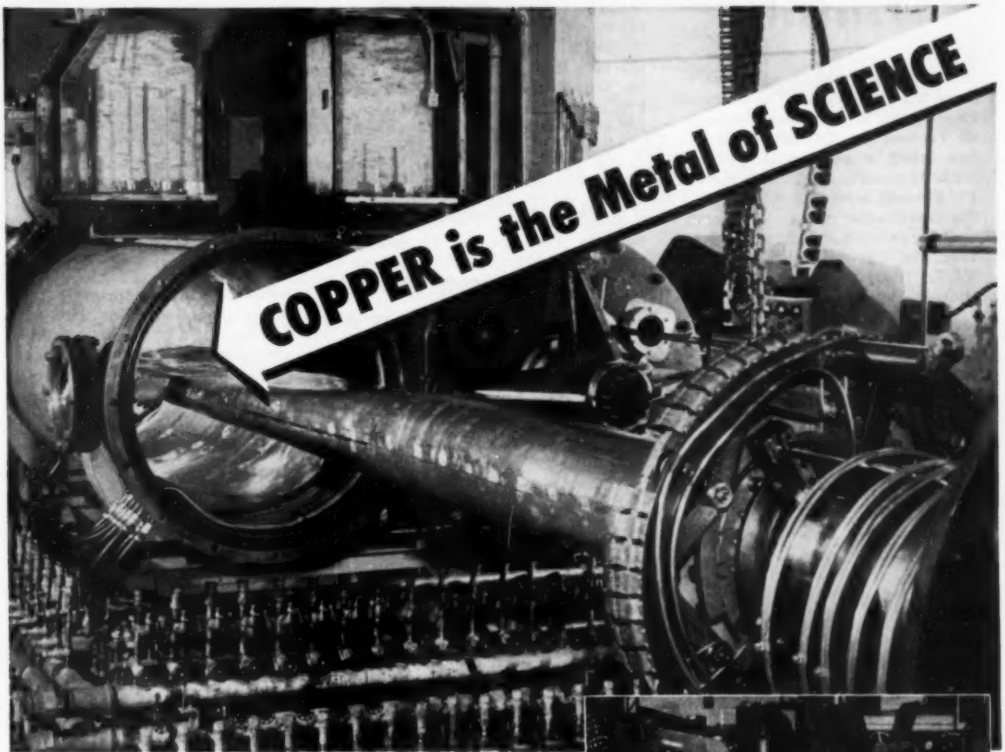
Kenneth D. Kelly ⊕ has accepted a position with the Oil Well Supply Co., Oil City, Pa., where he is on the training program which leads to the foundry metallurgy department. He graduated from Grove City College, Grove City, Pa., in June.

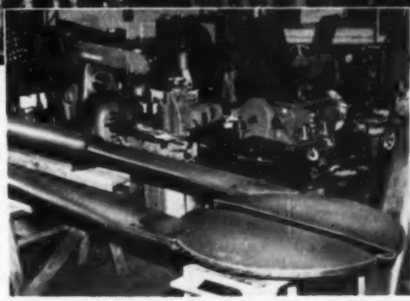
Richard B. Wagner ⊕ is now active as a consulting engineer, specializing in the field of metallic coatings.

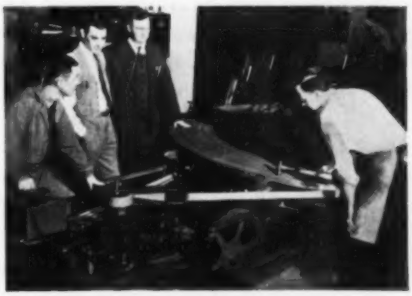
V. A. Crosby

VICTOR A. CROSBY ⊕, metallurgical engineer for Climax Molybdenum Co., in charge of sales, service and development in the Detroit area, was awarded the 1951 John A. Penton Gold Medal by the American Foundrymen's Society "for outstanding service and contributions to the ferrous foundry". Crosby ("Vic" to most everyone, including his wife) was born, raised and educated in the State of Mississippi, a circumstance which permanently warped his accent. He intended to be a sugar chemist, but instead (after discharge from the Air Force in World War I) became foundry metallurgist for Packard in Detroit and later for Studebaker in South Bend. He joined Climax in 1934. Vic has traveled widely, addressed numerous chapters of the A.S.M. and the A.F.S. on various aspects of foundry practice, alloyed cast irons, and castings for particular industries and uses. He has been chairman of the Detroit Chapter of the American Society for Metals and the American Foundrymen's Society, chairman of the division on automobile castings of the Society of Automotive Engineers, and active in handbook work for all of these organizations.

Edward N. Case ⊕ has been appointed product supervisor for metal trades product sales in the synthetic organic chemicals department, Industrial Chemicals Division, American Cyanamid Co., New York. He was formerly group leader of the company's metal trades laboratory, Technical Service and Development Division, Stamford, Conn.


COPPER is the Metal of SCIENCE





Personals

John T. Burwell, Jr., ⊕, formerly associate professor of mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass., has taken a permanent position with Horizons, Inc., Cleveland. Dr. Burwell served in the Office of the Coordinator of Naval Research and Development from 1942 to 1946, on leave of absence from M.I.T. He is the author of the ⊕ book, "Mechanical Wear".

Robert C. Shnay ⊕, who finished his graduate degree requirements at the University of British Columbia last June, has been employed by the Department of Mines, Physical Metallurgy Division, Ottawa, Ont., as a research engineer.

William E. B. Mason ⊕ has transferred from his position as inspector-supervisor at the Toledo Refinery, Pure Oil Co., to that of assistant quality control engineer for the American Locomotive Co., Dunkirk, N. Y.

Daniel L. Weller ⊕ has been working as a shift metallurgist at Crucible Steel Co. of America, Sanderson-Halcomb Works, Syracuse, N. Y., since he graduated from Carnegie Institute of Technology in June.

E. J. Walker ⊕, who has been foreman of experimental heat treatment in the main laboratory, Bethlehem Steel Co., Bethlehem, Pa., is now experimental engineer in the metallurgical department.

Robert L. Sauer ⊕, formerly job evaluation engineer for Timken Roller Bearing Co., Canton, Ohio, is now associated with Westinghouse Electric Corp., Headquarters Division, Pittsburgh, as a staff industrial engineer.

Randall E. Britt ⊕ has accepted a position with Howard Foundry Co., Chicago, in the Magnesium Division. He was formerly employed by the Engineer Research and Development Laboratories, Fort Belvoir, Va.

Harry J. Weil ⊕ has been employed as a metallurgical engineer by the Phillips Petroleum Co., Bartlesville, Okla., in the test division of the engineering department, since his graduation from Lehigh University last June.

John A. Milko ⊕ has taken a position as metallurgist at Oak Ridge National Laboratory, Oak Ridge, Tenn., where he is employed on the alloy development program of rare earth metals.

T. Roy Evans ⊕, a June graduate from Missouri School of Mines, has accepted a position as engineer to do titanium development work at E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

Clayton L. Nelson ⊕ has been transferred from his position as assistant resident engineer at the Flint, Mich., plant to the position of associate resident engineer at the Tonawanda, N. Y., plant of the Chevrolet Motor Division, General Motors Corp.

David B. Ballard ⊕, who graduated from Virginia Polytechnic Institute last June, has been employed as junior metallurgist at National Bureau of Standards, Metallurgical Div., Washington, D. C.

Harold Meese ⊕ has been recalled to active duty with the Navy and is assigned to duty with the Office of Naval Material, Washington, D. C.

Personals

Charles O. Hlavacek has been employed as a laboratory investigator in the main laboratory at Bethlehem Steel Co., Bethlehem, Pa., since his graduation from Michigan College of Mining and Technology in March.

Vernon H. Jones has been employed by Hayes Steel Products Ltd., Merriton, Ont., as a metallurgical engineer.

Keki K. Irani is now working in the openhearth department of the Granite City Steel Works, Granite City, Ill.

Roy H. Curtis, June graduate of Carnegie Institute of Technology, is now employed as a student engineer, Chrysler Institute of Engineering, Detroit.

Byron F. Campbell has been appointed executive engineer for Harry Ferguson, Inc., Detroit. He has been chief of the company's laboratories for the past six years.

David L. Zimmerman has accepted a position as technical graduate on the rotational training program, General Electric Co., Hanford Works, Richland, Wash. He graduated from the University of Wisconsin last June.

W. R. Hibbard, Jr., has taken a new position in the research laboratory at The Knolls, General Electric Co., Schenectady.

George D. Cremer, formerly resident consultant to the Oak Ridge National Laboratory, Metallurgy Division, has taken a position with the Research Division, Solar Aircraft Co., San Diego, Calif.

Arnold G. Mosier, who recently graduated from the Colorado School of Mines, has been employed as an analytical chemist by the Colorado Analytical Uranium Ore Project, Grand Junction, Colo.

Harold G. Bowen, Jr., has been head of the Armor, Projectile, Bomb, Ballistic, Rocket and Guided Missile Warhead Branch, Research and Development Division, Bureau of Ordnance, Washington, D. C., since completing the senior course in strategy and tactics at the Naval War College, Newport, R. I.

Kenneth D. Morland has been promoted to acting principal surveyor of American Bureau of Shipping's Chicago office.

Willard H. Hawley, Jr., a recent graduate from Yale University, has been employed by the Navy Department, Bureau of Ships, Washington, D. C.

John L. Blazich has accepted a position as plant superintendent with Shippers' Car Line, Inc., Milton, Pa. He was formerly assistant engineer in the improvement section, American Car and Foundry Co., New York.

Charles R. Johnson has been employed in the metallurgical laboratory of Globe Steel Tubes, Milwaukee, since his graduation from Purdue University last June.

Robert J. Morris, who graduated from Missouri School of Mines and Metallurgy in June, has been employed as a metallurgist for the Allison Division, General Motors Corp., and is working in the materials laboratory, Indianapolis, Ind.

Donald F. C. Cole has joined the staff of Metals and Alloys Ltd., Montreal, Quebec, as sales manager for Quebec and Eastern Canada.

Personals

Paul A. Beck has accepted a research professorship in metallurgical engineering at the University of Illinois, Urbana, Ill.

Truman J. Hammel has recently joined the sales division of Chain Belt Co., Kansas City, as district sales engineer. He has been with the company, in the research engineering division, since 1946.

Carl A. Liedholm is now in Sandviken, Sweden, where he is starting an extensive study of hollow rock-drill steel for Sandvik Steel Works. He writes: "Understandably enough, steel airplane propellers — my wartime preoccupation with Curtiss-Wright — and hollow drill rods have much in common, and least in their ability to withstand fatigue."

George V. Luerssen, formerly chief metallurgist, has been appointed vice-president in charge of metallurgy by the board of directors of the Carpenter Steel Co., Reading, Pa. **Carl B. Post** succeeds Mr. Luerssen as chief metallurgist, and **George E. Brumbach** has been advanced to the position of metallurgist to succeed Mr. Post.

T. W. Merrill has been appointed chief metallurgical engineer of the Vanadium Corp. of America and has been transferred from the company's plant at Bridgeville, Pa., to the executive offices in New York.

W. G. Dahl has been appointed district manager of the Hartford, Conn., area by the Latrobe Electric Steel Co. He replaces **H. C. Cole** who has resigned from the company.

L. P. Josephs, owner of Pearson Industrial Steel Treating Co., Chicago, announces the following changes: **Victor Bozick** has been promoted from plant superintendent to works manager; **Carlton M. Fallert**, formerly with Lindberg Steel Treating Co., has charge of purchasing and quality control; **Alfred Francis**, previously with the West Pullman Works of International Harvester Co., has been appointed metallurgical engineer in the sales department; **Raymond Ericksen**, who was formerly associated with the National Malleable and Steel Castings Co., has been engaged as plant metallurgist and superintendent.

Low Temperature Properties of Iron and Steel*

Applications for ferrous materials at low temperatures have increased until they now embrace certain areas in most basic industries as well as many types of military, marine and civilian needs. Conditions vary widely as to temperature, the type of service, and the character and design features of a part. The properties required of the metal in service, to insure that it will function with a high degree of safety at service temperatures, will also vary widely, though the exact requirements are apt to be difficult to specify.

It should not be construed that the use of ferrous materials at low temperatures introduces major problems of selection in every case. When, for example, materials must withstand static loads only, there may be no necessity to employ a material other than that which is satisfactory in the same application at normal temperatures. The lower temperatures strengthen and harden ferrous materials slightly so that for construction involving static loading only, it is possible that they are as good at low as at normal temperatures. As the severity of service increases, however, and materials are called upon to withstand the possibilities of shock loadings and local deformation without failure at low temperatures, increasing care must then be exercised in selection.

The conventional engineering tests on ferrous materials have provided information to show that, as the temperature of testing is decreased below atmospheric, the hardness, yield strength, fatigue strength and tensile strength increase, except for highly embrittled materials. This is not so, however, for ductility, manifested by the degree of permanent deformation before fracture by stress in tension, and for toughness, manifested by the amount of energy absorbed before fracture. With respect to these two properties, ferrous materials fall into one of two groups; namely, those which remain ductile at low temperatures and those which become embrittled.

It is characteristic of the body-centered-cubic ferritic materials to

(Continued on p. 100)

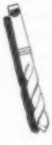
*Abstract from "Low Temperature Properties of Ferrous Materials", compiled by the S.A.E. Iron and Steel Technical Committee, Society of Automotive Engineers, Inc.

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

High-Speed Tools at Lower Cost with Tungsten-Saving 66HS

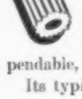
Bethlehem 66HS performed so well during the alloy shortages of World War II that many users of high-speed steels never did go back to the large-scale use of 18 pct tungsten grades. 66HS has a balanced content of tungsten and molybdenum; and it has proved ideal for a wide variety of cutting tools. Because of its lower cost and many uses it is much more than just an able substitute for the high-tungsten steels.



In Bethlehem's own machine shops, for example, 66HS has been used since 1942 for more than 90 pct of all our high-speed tools. We use many tons of it each year; and our production men report that year after year this grade performs just as well or better than Special HS, our 18-4-1 type of steel.

There's an economy angle to 66HS that shouldn't be overlooked, especially by large users. 66HS at present prices costs about $700 a ton less than standard 18-4-1 grades. And it's 6 pct lighter, too.

66HS is hardened at 100 degrees below the hardening temperature for high-tungsten grades. It requires careful heat-treating, but it presents no problem at all to any heat-treater who has accurate temperature indicators. This equipment is necessary because 66HS does *not* form beads of "sweat" on the surface when the proper hardening temperature is reached (2250 to 2275 F).

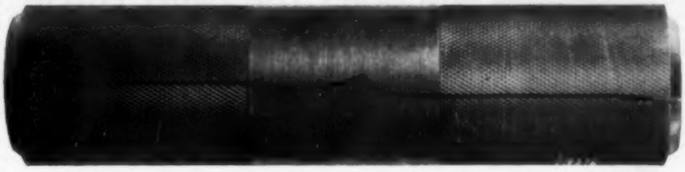


66HS has just the right degree of wear-resistance, toughness, and red-hardness for use nearly everywhere as a dependable, general-purpose cutting steel.

Its typical analysis:

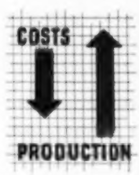
C	W	Mo	Cr	V
0.83	6.35	5.0	4.15	1.90

Like to know more about it? Ask for our Booklet 264, describing 66HS and other Bethlehem high-speed steels.



This 1⅜-in. diameter gage, made from oil-hardening tool steel, cracked because it wasn't tempered immediately after the quench. Tempering relieves stresses set up in the steel during hardening.

Tool Steel Troubles Usually Have Happy Endings



Based on the many thousands of investigations they've made, our metallurgists and research men say that probably less than 3 pct of tool failures can in any way be blamed on the tool steel.

Tool failures are usually cured by one or more of these remedies:

1. Improving the tool design
2. Using a more suitable tool steel
3. Correcting the heat-treatment
4. Improving tool-grinding technique

Some people who think they don't have tool problems quite often aren't getting best results. For example, a plant may suddenly have a series of broken tools or dies. We're called in to help put a finger on the cause. And quite likely we'll find they have been overlooking some vital factor in tool design or heat-treatment. Correcting the trouble leads to tool performance that's far beyond the best previous service life. That's why most tool steel troubles have a happy ending.

If you have a problem involving tool steel or feel you should be getting better tool performance, let us hear from you. Maybe we can give you the right answer pronto. Or a Bethlehem metallurgist may have to work with you in your shop. In either case, there's no obligation.

Our Tool Steel Engineer Says:

Making shock tools too hard causes premature failure

Most shock-resisting tool steels give best service when hardened between Rockwell C-55 and 60—averaging about C-58. This hardness range provides the best compromise between toughness and wear-resistance. Premature failure is often the result of obtaining an excessively high hardness in these grades. Carbon tool steels are often best for shock tools requiring a hardness above Rockwell C-59.

The chrome-tungsten grades of shock-resisting tool steel can be carburized to obtain greater wear-resistance. This treatment produces a thin, hard case on the tool surfaces, yet retains a tough core of lower hardness. This method is often used for master hobs, reamers, swaging dies, and various kinds of shock tools.

Bethlehem ULTRASONIC TESTED **Tool Steel**

Low Temperature Properties

(Continued from p. 98)

show brittle behavior at some low temperature, the materials differing among themselves only in the temperature at which ductility vanishes in a specific test. On the other hand, the austenitic-type materials of face-centered-cubic structure tend to remain ductile over most ranges of low temperatures that have been investigated. They seem to become sensitive to embrittlement only when they contain sigma phase, are made subject to precipitation hardening, or are structurally unstable at low temperature.

The fracture behavior of ferritic materials is known to change profoundly with lowering temperature, the change often being characterized by a sudden loss in toughness or ductility. The temperature of change from ductile to brittle behavior is frequently referred to as the transition temperature though this temperature need not be and usually is not the same when determined by different test procedures. Variations in conditions of determination of ductility or toughness affect the transition temperature; it is dependent upon factors relating to both external and internal conditions imposed on or existing within the material when subject to fracture. Different methods of testing, with few exceptions, will place several steels in the same order with regard to their transition temperatures. A necessary consideration then, in evaluating a testing procedure, is its sensitivity in differentiation between two steels of like properties.

In service, the size and geometry of the part, the presence of surface blemishes, scratches, and deep notches, and the simultaneous action of *(a)* a high rate of straining, *(b)* a nonuniform stress distribution, *(c)* a multiaxial state of stress, and *(d)* a low temperature, are some external conditions which affect the embrittlement. Although these are extremely important, other factors related to the internal state of the metal are likewise important to the problem of brittle behavior. Among the latter are chemical inhomogeneities, internal discontinuities and cracks, grain size variations, grain orientation, residual stress, strain hardening or cold working, strain aging effects and state of deoxidation.

The general effects of low tem-

(Continued on p. 102)

Low Temperature Properties

(Begins on p. 98)

peratures on mechanical properties of ferrous materials might then be summed up by stating that, for the most part, properties are improved with decreasing temperature, and it is only the ferritic materials as a class that become embrittled at some temperature. The temperature where transition from ductile to brittle fracture occurs varies considerably, depending on the nature of the test and on both external and internal factors existing prior to and during fracture.

Some progress has been made in correlating results of conventional tests with service performance of materials at low temperatures, but designers are cautioned to use extreme care in interpreting such results in terms of material performance. All conventional tests for embrittlement provide arbitrary measures of the ability of material to resist fracture under conditions of restriction on deformation. None seem capable of integrating all the variables significant to the problem of embrittlement. For that reason, reliance can be placed on only those tests which more nearly simulate conditions in service or, at least, which have been shown by experience to give satisfactory indications of the behavior of material in its particular reduced temperature environment.

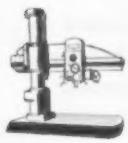
The function of the notch in the notched-bar specimen is to accentuate the effective strain rate and to provide the degree of constraint necessary to differentiate, at room or at moderately reduced temperatures and at moderately low rates of loading, between materials that will be ductile and those that will be brittle when subjected to service at either very low temperatures or under conditions of extreme shock loading or both. The V-notch specimen, because of the relative severity of the notch, is preferred for measuring the impact resistance of quenched and tempered steels of moderate to high strength levels intended for fairly severe service applications involving low temperatures and shock loading. Because of the severity of the notch, the V-notch specimen provides a sharper distinction between the applicability of steels to low temperature conditions.

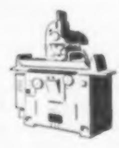
The effect of velocity is important in impact testing. Increasing

(Continued on p. 104)

Machine Tool Staying Power

Upped





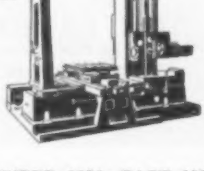
BY THESE 4 STEPS

1st step: Examine Cities Service lubricants for out-and-out quality through your purchasing experts or test facilities . . . or from service records established by critical users.

2nd step: Look into the completeness of the Cities Service line as an aid to simplified ordering and prompt, steady supply . . . backed by the extensive facilities and intensive cooperation to keep you out of any lubrication "jam."

3rd step: Review today's most effective lubrication practices by consulting that fully informed specialist, the Cities Service Lubrication Engineer.

4th step: Ask for facts about the high character of the Cities Service line and the practical technical assistance now upping machine tool staying power for many of industry's "hardest drivers." Phone or write CITIES SERVICE OIL COMPANY, Room 112, Sixty Wall Tower, New York City 5.



CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

Low Temperature Properties

(Begins on p. 98)

the velocity increases the severity of the test and tends to promote increasingly brittle behavior. Until the effect of striking velocity is fully understood and standardized, the striking velocity should be recorded with all data.

Composition — Increasing the carbon content of a steel causes a rapid decrease in room temperature notched-bar impact results and tends to increase the temperature of transition or embrittlement. The resistance to embrittlement at low temperature does not depend so much on the quantity of carbon present as on the degree of dispersion. A fine spheroidal dispersion of iron carbide is least detrimental to low-temperature properties. A contributing factor to low impact values for high-carbon steels may be the tendency of the higher carbon steels to exhibit quench cracking under some conditions.

Manganese content up to about 1.5% has a beneficial influence on the low-temperature embrittlement of low-carbon steel, but larger quantities are detrimental. In steels which are sensitive to temper embrittlement, manganese has a detrimental effect on low-temperature embrittlement. An increase in the silicon content of carbon and medium alloy steels considerably reduces their notched-bar impact resistance. This effect has been demonstrated in carbon and alloy steels over the entire range of microstructure from martensite to pearlite. It is advisable to keep sulphur and phosphorus as low as possible in those steels intended for low-temperature service.

The ideal structure to obtain a minimum transition temperature at a given hardness for ferritic steels is tempered martensite. Slack quenching, such as occurs in the interior of a large quenched section of a steel of insufficient hardenability, will produce mixed structures or structures which are not the equivalent of martensite in low-temperature behavior. The primary reason for adding alloying elements is to increase hardenability and in this way to aid throughout in developing the desirable martensitic structures.

The effect of chromium in promoting hardenability aids in developing full hardening in the steel which on tempering produces the

(Continued on p. 106)

Low Temperature Properties

(Begins on p. 98)

spheroidal carbide structures so desirable for low-temperature impact resistance. When used alone, chromium may have a tendency to promote embrittlement if the steels are tempered in the normal ranges. Molybdenum, as a carbide former and hardenability promoter, performs one of its chief functions by producing desirable microstructures in quenched and tempered parts. A recognized use for molybdenum in alloy steels is its property of inhibiting the temper embrittlement of susceptible steels. Molybdenum up to 0.5% is used to minimize this phenomenon.

Nickel as an alloying element in ferrous base materials is regarded as beneficial in preserving toughness at subnormal temperatures. A noncarbide-forming element which is soluble in ferrite, nickel is not dependent on carbon for its major alloying effect and, therefore, it may be employed effectively in low-carbon iron and steel. A low carbon content also is very desirable in promoting low-temperature toughness, particularly in structures of a type or size where normalizing and tempering are the most drastic treatments possible. The quenched and tempered state is the most desirable.

No conclusive data are available regarding the effect of copper on low-temperature properties of steel. What is known indicates that copper in solution is mildly beneficial; in the age hardened or precipitated state it has an adverse effect on low-temperature ductility. Data available are not extensive enough to draw conclusions regarding the effect of vanadium, columbium, aluminum, titanium and zirconium.

Vanadium increases hardenability whereas aluminum, titanium and columbium decrease it. In general, they raise the grain coarsening temperature. Their ability to fix oxygen, nitrogen and sulphur and to promote fine grain size is beneficial to low-temperature notch impact. There are optimum additions of these elements above which no further benefit may be derived or detrimental results accrue. No data are available relative to the direct effect of tungsten.

Nitrogen has been shown to give rise to precipitation or aging effects when present in amounts ordinarily found in low-carbon iron and steel.

(Continued on p. 108)

ACME MANUFACTURING CO.

INVITES YOU TO VISIT THIS NEW PLANT!...

...WHEN YOU VISIT THE NATIONAL METAL EXPOSITION AT DETROIT, OCT. 15-19

Our new plant is located about 5 minutes north of Michigan State Fair Grounds where the exposition is to be held. If you are interested in automatic polishing, buffing, deburring, grinding or micro-finishing, you will find the displays at our plant more extensive than is possible at our booth at the show.

Acme Automatics have proved their production efficiency and dependability in industry for nearly half a century, solving a wide variety of finishing problems on a practical production basis.

The progressive development which has characterized these machines is reflected in our new plant and increased facilities for engineering and experimental processing . . . . which can help solve YOUR finishing problems.

Transportation will be furnished to and from our plant. Check at our Booth #D-103

ROTARY
STRAIGHT LINE
SEMI-AUTOMATIC
AND SPECIAL
Polishing and Buffing
Machinery

ACME *Manufacturing Co.*
1400 E. 9 MILE RD., DETROIT 20 (Ferndale) MICH.
Builders OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR NEARLY HALF A CENTURY

Low Temperature Properties

(Begins on p. 98)

The effect of increasing nitrogen content is to decrease the impact resistance and raise the transition temperature. Although there are indications that oxygen itself does not cause aging, it seems to have a secondary influence on the amount of nitrogen or carbon required to cause aging. The embrittling effect of oxygen in steel and iron is modified perceptibly by the presence of strong deoxidizers. The effect of hydrogen on the embrittlement of steel and iron at low temperatures appears not to have been determined as yet.

Influence of Steel Making — Optimum properties for a wrought steel of given composition and structure are obtained when it is fully killed with aluminum in sufficient quantities so that a definite amount is retained in solid solution (between 0.02 and 0.08% Al). This treatment lowers the oxygen content of the steel and produces a fine-grained material. The bulk of the evidence seems to indicate that carefully controlled deoxidation with aluminum should improve the low-temperature properties of cast steels. The part played by grain size is not so clearly brought out as in the case of wrought steels. However, the fine-grained material performs the best. Normalizing or heat treatment will give higher values for impact.

Influence of Microstructure — Although the effect of mixed structures, resulting from heat treatments other than full quenching, still remains to be determined quantitatively, the studies reported in the paper by Stout and McGeady, *The Welding Journal*, 1947, p. 683-S to 692-S, show the importance of metallurgical structures. Grain size exerts a marked influence upon the toughness of steel at reduced temperature. For any given strength level, fine-grained steels generally possess significantly higher notched-bar impact values than coarse-grained steels, and also retain their toughness down to lower testing temperatures.

Temper embrittled fine-grained steel possesses approximately the same toughness at all testing temperatures as the same steel in the unembrittled but coarse-grained condition. The specific effect of small additions of various alloying elements in increasing the low-

(Continued on p. 110)

Low Temperature Properties

(Begins on p. 98)

temperature toughness of steel may not be due to the alloying effects of the added elements but traceable to their influence upon the grain size.

Enough evidence is now available to indicate that constituents, whether ductile or brittle, in continuous or network arrangement in metal are harmful. Treatments which tend to destroy the network envelopes or make the constituents less continuous in form will provide some improvements in toughness, ductility and notch-resistivity at low temperatures.

Banding and laminations are undesirable. Inclusions are detrimental also but vary in degree according to their form and distribution. Small, hard, angular particles are the least desirable type.

(A concise discussion on heat treating, tempering, temper embrittlement, and quench and strain aging is included. Of particular interest here is the quench from tempering temperature to avoid temper embrittling effects. It is possible to minimize the effects of temper brittleness by selecting an alloy composition which has a high resistance to softening so that a tempering temperature in excess of 1100° F. will be required to produce the desired hardness. It will then be possible to water-quench after tempering and avoid embrittlement. When the tempering temperature must be below 1100° F., the highest temperature and shortest time practicable should be employed, followed by a water quench after tempering.)

Effect of Welding — All factors which affect the notch toughness of steel affect the notch toughness of weld metal. The welding process has little effect on an unnotched tensile specimen in terms of yield point, ultimate strength, reduction in area, and per cent elongation. The evidence, however, points to the fact that welding has an adverse effect on the notch toughness of steel. This detrimental effect of welding on notched specimens has been confirmed by a variety of tests.

Welded structures which are well designed and constructed with consequent elimination of any type of notch effect will perform extremely well.

The performance and strength of a welded structure are influenced by the use of different types of

(Continued on p. 112)

industrial x-ray calls for special accessories

for example...

Take the heavy-duty Picker Industrial X-Ray Cassette. The girder-section frame is welded and reinforced all around . . . hard knocks won't spring it out of true. The thick aluminum back-up plate gives square support, keeps the front from sagging under the weight of heavy castings. The cassette stays lighttight, maintains good contact . . . and lasts a long, long time.

Just as special as the cassette shown here are the plastic flexible film holders that Picker makes for industrial radiography. They come in a wide range of shapes (including long, narrow ones for X-raying welded seams). They're so supple, even when loaded, that they follow curved or awkward contours easily. And they're tough enough to take the beating of heavy-duty service.

You'll find many another special-purpose accessory in this newly-issued Picker X-Ray Industrial Accessory Catalog . . . it's crammed with useful things for the industrial radiographer. Get a copy from your local Picker representative . . . or write to Picker X-Ray Corporation, 300 Fourth Avenue, New York 10. And remember . . . for anything having to do with X-ray equipment—equipment, supplies, or service—*you'll do better at PICKER.*

yours for the asking...

Anywhere you open the Picker Industrial X-Ray Accessories Catalog you'll find something of interest . . . everything from Aprons to X-Ray Protective Construction. Send for your copy now.

Picker x-ray

PICKER X-RAY CORPORATION
300 Fourth Avenue, New York 10, N. Y.

Low Temperature Properties

(Begins on p. 98)

electrodes, preheating, postheating and special welding procedures. This is confirmed by work of Grossman and Shepler who determined the transition temperatures to brittle fracture of various types of electrodes and welding methods. It is immediately evident from their graphs that the lime-coated ferritic electrodes (A.W.S. 6015) and the process of automatic welding gave very low transition temperatures in the weld metal as compared to the unaffected base plate. The highest transition temperature is encountered about 1 in. from the center of the weld. The use of E6020 electrodes shows better results than E6010. The latter shows its worst effect at the fusion zone, while the E6020 electrode reaches the highest transition temperature well in the heat-affected zone. The oxyacetylene welding process has been found to offer the poorest results, the zone most affected being the center of the weld.

Influence of Design — There is no fundamental difference in the influence of the various design factors upon the behavior of steel parts at reduced temperatures as compared to room temperature. There is, however, a difference in magnitude of the effects of design upon the performance of steel structures at reduced temperatures. Stress concentrations and triaxial stress patterns should be designed out of a structure to be subjected to low-temperature service.

Wherever possible, thin sections should be utilized in the design because: *(a)* the increased constraint upon local deformation impaired by the surrounding mass of rigid metal promotes the brittle type of fracture; *(b)* it is more difficult to obtain the tough, tempered martensite microstructure in heavy sections; *(c)* with the higher alloy needed to get full hardening in heavier sections, the metallurgical difficulties of temper embrittlement and quench cracking are more prevalent.

Steel parts subjected to fatigue at low temperatures have an increased resistance to crack initiation; but, once the crack is initiated, it will propagate to complete failure at a much more rapid rate than at normal temperatures. Therefore, care must be taken to avoid high stress concentrations.

(Continued on p. 114)

Low Temperature Properties

(Begins on p. 98)

Surface Condition and Finish — Surface hardening treatments result in a part with a hard surface layer having a residual stress pattern varying according to the treatment and depth of case; consequently, this layer is very notch-sensitive. It is thus even more important that such parts be free of any notch effect. Steels and thermal treatments should be so specified that the core material will have an adequate degree of toughness. Thus, carburized steel parts are not recommended.

Surface imperfections such as scratches, machine tool marks, stamped-in numbers, and other flaws may be focal points of failure of severely stressed parts.

Steels for Low Temperatures — It is apparent that no set rule exists to govern the selection of a steel for a particular low-temperature application. In the design of components, the variables must be considered separately on the basis of the following factors: Type and distribution of stress, rate of strain, specific temperature range involved. In general, the more severe these conditions are, the lower must be the transition temperature of the steel in the Charpy test.

The ideal microstructure to obtain a minimum transition temperature in ferritic steel is tempered martensite. Hardenability is, therefore, an important factor. In addition, deoxidation, grain size, and susceptibility to temper brittleness must be considered.

It is not feasible here to repeat the long discussion on the selection of steels for service under increasingly low temperature, or to condense it. It is sufficient to state that suitable steels are available for service under all conditions of temperature, running from plain carbon through to the austenitic types as conditions become increasingly severe. The steel's alloy content alone is no criterion of its behavior because heat treatment, melting and deoxidation practice, grain size, tempering treatment, design, and other factors all play their roles. At very low temperatures, great care must be taken in the application of welding and other types of postheat treatments.

Specification Limits — It would be unwise to attempt to specify any given test or a range of test values to be used to control quality of

(Continued on p. 116)

Low Temperature Properties

(Begins on p. 98)

materials for use at low temperatures under all service conditions. Therefore, it is suggested that a material and test to control the desired properties be selected for a given operation. After material and test have been selected, then test values should be established through actual test at the lowest temperature at which the material is to be used in service.

The range of specification limits should be established only after careful correlation with service performance. Caution should be taken to avoid establishing requirements on limited data, since it is possible to have service temperatures which fall in the transition zone for the material being used, and results could be obtained which could not be readily reproduced.

H. J. NICHOLS and S. A. AGNEW

Centrifugal Castings for Aircraft Engines*

HIGH-ALLOY steel components for aircraft engines, which are generally cylindrical or disk-shaped, are reliably and economically produced by centrifugal casting. Firth-Vickers Stainless Steels, Ltd., Sheffield, England, has produced more than 1¾ million parts by its "Centrispinning" process, first for sleeve-valve piston engines, later for turbojet and gas-turbine engines.

The centrifugal method used is dependent on the shape and design of the component. Generally, if the length of the part is greater than the radial thickness, spinning about the horizontal axis is generally preferred, but if the radial thickness exceeds the length, the vertical method is often used. The cast component rotates about a true axis in either method during pouring and solidification. No cores are required where the internal shape is regularly cylindrical. Metal molds are preferred where their use is possible because directional solidification is assisted by the chilling action of the mold and finer grain is produced in the austenitic alloys.

(Continued on p. 118)

*Abstract of "Centrispun High-Alloy Steel Aero-Engine Components", by A. E. Thornton and J. I. Morley, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 189-194.

ACID ADDITION AGENT

Stops fuming of acids — promotes better wetting — lowers drag-out — saves acid — less harm to operator — less corrosion on surrounding equipment — more uniform pickling effective with sulphuric acid hot and cold — hydrochloric — phosphoric — hydrofluoric acids.

COMPOUND 42

A new cleaning and pickling agent combined—removes oil and rust at room temperature in *One* operation — prepares metals for painting — inhibits rusting — apply by dipping or brushing.

INHIBITOR 8

A new complete inhibitor to stop attack on base steel — high inhibition in sulphuric—hydrochloric—phosphoric acids —lowers surface tension—less drag-out —saves acid—reduces rusting after pickling — reduces fuming — bright pickling — makes pickling a more pleasant and healthful operation.

COMPOUND NR-37

Prevents rusting during drying but *leaves no* residue — added to hot or cold water it permits drying without rusting and leaves steel clean for painting — very effective for porous castings.

ENTHONE
INCORPORATED

Write for Check List
Sixty Products and Processes
for Metal Finishing

442 ELM STREET • NEW HAVEN, CONNECTICUT

Centrifugal Castings for Aircraft Engines

(Continued from p. 116)

Where an irregularly shaped part requires a refractory mold and refractory core the process is termed "semi-centrispinning" and the axis of rotation is usually vertical. With refractory molds there is always some tendency for erosion of the mold surface with consequent danger of entrapping nonmetallics in the casting. The castings produced in "permanent" metal molds therefore are generally cleaner of harmful inclusions.

To insure freedom from shrinkage porosity, due consideration must be given, as in static casting, to achieving directional solidification and to providing adequate metal for feeding. This is more easily accomplished in the centrifugal process where the first metal poured goes to the outer periphery and freezes first, and the last metal poured is nearest the center to feed outwardly into the solidifying part. To consistently achieve this desirable state of affairs, it is necessary in many cases to add feeding metal. This can be subsequently removed by machining. Much depends upon the correct control of speed of rotation, rate of pouring, and casting temperature.

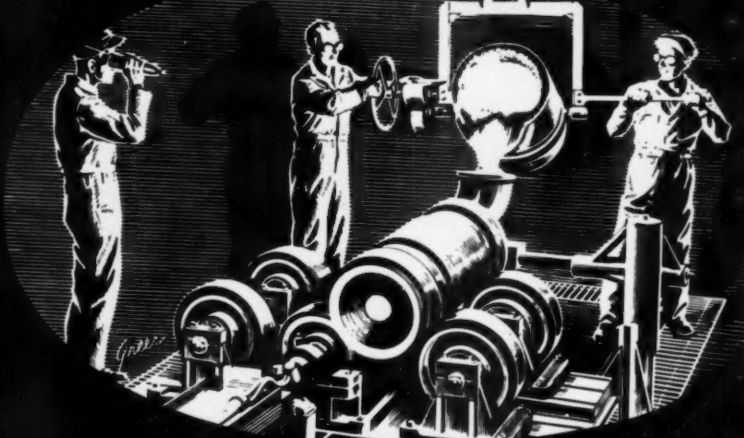
The advantages of centrifugal casting methods are summarized as follows: Highest quality of metal and freedom from defects or porosity; freedom from directional or center-line weakness; flexibility in production; and ability to process alloy compositions which are difficult to form by usual methods.

Quality control and inspection must be of the highest efficiency to insure that the quality of the outgoing product is consistent with the best possibilities of the centrifugal process. The detection of defects is somewhat simplified by the fact that in centrifugal castings the flaws are nearly always surface defects either on the periphery or in the core. Rough machining and then hot pickling or macro-etching is the most efficient method for inspecting austenitic steel parts.

Three steels which have been produced most extensively for turbo-jet and gas turbine applications are an 18-8 chromium-nickel stabilized with titanium, 18-12 chromium-nickel stabilized with columbium, and a 24-12 type with nearly 3% tungsten. The columbium-stabilized

(Continued on p. 122)

family



SPECIAL PRODUCTS DIVISION

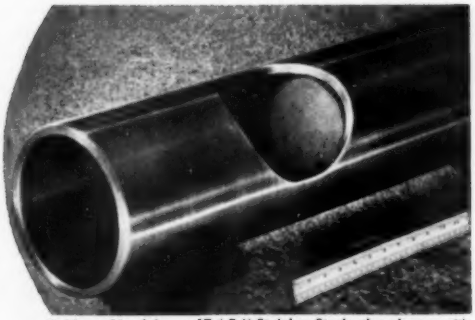
U. S. PIPE AND FOUNDRY CO., BURLINGTON, NEW JERSEY

AMERICA'S LARGEST PRODUCER OF CENTRIFUGALLY
CAST FERROUS METAL PRODUCTS IN TUBULAR FORM

SPECIAL PRODUCTS DIVISION USP

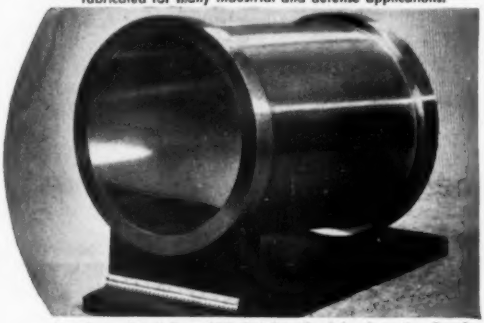
portrait!

METAL MOLD CENTRIFUGAL CASTING SPELLS ECONOMY AND EFFICIENCY FOR WIDENING GROUP OF STAINLESS STEEL PRODUCTS



Finish machined Armco 17-4 P H Stainless Steel valve plunger with welded plate and port for the paper industry.

Type 303 Stainless Steel stock from which rings and sleeves are fabricated for many industrial and defense applications.



Rough machined Type 316 Stainless Steel bowl casting for the food and processing industries.

Pictured here are a few of the many stainless steel products now included in the rapidly increasing family of products centrifugally cast for industry by our new metal mold process.

This method offers many specific advantages. For one, centrifugally cast stainless steel cylindrical sections, formed by pouring molten metal into rapidly spinning, refractory-coated permanent metal molds represent the ultimate in casting quality, imparting a fine, dense grain structure, unusually free from conventional casting defects.

You may find that your stainless steel product can be cast more advantageously by this versatile process. Our engineers will be glad to answer any of your questions.

SIZE RANGE AND COMPOSITION FLEXIBILITY

Outside Diameter — 4" to 30"

Wall Thickness — 3/8" and up

Length — Up to 14' in the "as-cast" condition

Types of Stainless Cast — All standard AISI and ACI grades of ferritic and austenitic stainless, plus "Special" types

CHECK THESE ADVANTAGES FOR YOUR CYLINDRICALLY-SHAPED PRODUCTS:

- Reduced Processing Time and Increased Production.
- Minimum Scrap Loss.
- Design of parts to suit the specific job requirement by selecting the correct alloy — not the next best available alternate.
- Conservation of critical metals and alloys — especially on tubular parts now produced from solid sections.

Centrifugal Castings for Aircraft Engines

(Continued from p. 118)
alloy with 12% nickel has the best creep properties but is not easy to cast and is sensitive to hot tearing. The higher chromium alloy with tungsten has the best scaling resistance and good casting properties. The titanium-stabilized alloy has good ductility and adequate stability but may have titanium-rich inclusions to which some engineers object.

It is apparent from this paper that the centrifugal casting practices in England embody no new principles not already well proved in this country. The control and inspection practices to insure optimum quality have apparently been developed to a very high degree. C. K. DONOHO

High-Tensile Structural Steel*

STRENGTH of steel may be enhanced by *(a)* cold work, *(b)* heat treatment or *(c)* the addition of alloying elements. For structural purposes, where steel is used in as-rolled condition, only the third method has widespread application. The main requirements for a good structural high-tensile steel are sufficient strength to permit saving in weight commensurate with added cost, good plastic range to reduce the adverse effects of stress raisers such as notches, good ductility and impact strength, high fatigue resistance, ease of fabrication, weldability and improved corrosion resistance.

Weldability of high-tensile low-alloy steels has been improved by limiting the carbon content and introducing special alloying elements, such as titanium, molybdenum and vanadium. Considerable effort also has been directed toward better welding technique, including the use of special electrodes, most favorable gage of electrodes and optimum welding speeds. From the corrosion point of view, copper-nickel-chromium compositions show to advantage but the carbon-silicon-manganese group has no particular merit.

While the usual high-tensile steel in British use has a yield stress 50%

(Continued on p. 124)

*Abstract of "Structural High-Tensile (Low-Alloy) Steel", by O. A. Kerensky, *Engineer*, March 1949, p. 238-241.


HEAT TREATING FURNACES
For ALUMINUM
Aging • Pre-heating
Solution heat treating
For FERROUS METALS
Stress relieving • Normalizing
Aging • Tempering • Drawing
For all heating requirements up to 1350° F. where accurate heat control and uniformity in the work chamber is desired. Car bottom furnaces. Bottom entry quick quench furnace for solution heat treatment of aluminum. Conveyorized furnaces and all other material handling designs.
DESPATCH
Laboratory furnace for research and production control.
Battery of Despatch pot type furnaces heat treating steel parts.
Despatch Stress Relief Furnace, gas fired car bottom type. Has automatic pre-heating, soaking and cooling control.
Despatch continuous conveyor furnace for steel heat treating.
DESPATCH
OVEN COMPANY
Write to Dept. P for more information.
Minneapolis Office:
619 S. E. 8th St.
Chicago Office:
4554 Broadway

High-Tensile Structural Steel

(Continued from p. 122)

higher than that of mild steel, the practice of bridge engineers has been conservative and the allowable working stresses have been increased only 40% in general. Apparently, this conservative position has been taken because of the limited experience with the newer steels.

The selection of suitable steel for a structure is governed by technical considerations, such as where lightness is obtained with use of superior steel as in bridges for military use, or where corrosion resistance must be obtained; or by commercial factors where the use of superior steel results in a structure of lower cost. The first cost of steelwork in a structure is made up of seven main items: Costs of *(a)* plain material (high-tensile structural steel requires the addition of alloying elements involving addition costs, not only in the supply of the alloys, but also in the increased difficulties in production), *(b)* fabrication, *(c)* transport, *(d)* erection, *(e)* painting, *(f)* overhead, and *(g)* profit. The author analyzes the situation for an average structure in Great Britain and shows that, if the percentage weight saving resulting from the use of high-tensile steel is P, the saving is cost of steelwork is approximately ($\frac{1}{2}$P − 3). The weight saving anticipated by the use of high-tensile steel in various girders and joists is computed and ranges from 6 to 27%, depending upon section, span and loading.

There are general advantages to the industrial economy resulting from the use of high-tensile steels so that their more extended use in structures seems justified even though the monetary saving in the individual case may not be large.

S. FEIGENBAUM

Gas-Turbine Materials*

THE SPECIAL material problems of large closed-cycle gas turbines, as distinguished from open-cycle plants, center on the air heater, where long life is required of tubes working at temperatures up to

(Continued on p. 126)

*Abstract of "Gas-Turbine Performance and Materials", by J. B. Bucher, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 17-23.

STEP AHEAD

of your competition . . .

Alert, aggressive suppliers to the nation's giant metal industries will be way out in front of their stay-at-home competitors by showing their products at the *biggest* and *finest* National Metal Exposition in history!

More than 45,000 metal industry folks will be at this great Show . . . they'll be in a buying mood and they'll be hungry for ways and means to step up production. Make up your mind right now to be on the firing line when this vital Show opens its doors in October. Write, wire or phone . . .

NATIONAL METAL EXPOSITION
c/o American Society for Metals
7301 Euclid Ave., Cleveland 3, Ohio
Telephone—UTah 1-0200

NATIONAL METAL EXPOSITION
•
NATIONAL METAL CONGRESS
•
WORLD METALLURGICAL CONGRESS

Oct. 15-19 · Detroit, Michigan

Gas-Turbine Materials

(Continued from p. 124)

1500° F. with maximum operating stresses of the order of 3500 psi. It is unsatisfactory to extrapolate creep and rupture data from tests of only about 5000 hr. duration to time periods of 100,000 hr., and the author makes a plea for a few check points at 20,000 to 50,000 hr.

Another problem unique with the closed cycle is that the tubes are cold worked in manufacture, and for most materials it has not been determined how this affects the creep and rupture life or what heat treatments may be required subsequent to cold working to restore the inherent strength of the alloy. If a solution treating temperature of the order of 2300° F. is required, this probably would be found impractical due to the long lengths of tubes. The tubes must also be joined to one another and to the tube sheets by welding, and adequate data are not available for most materials on weldability and the high temperature strengths of welds.

The most serious problem encountered thus far, however, is corrosion from fuel oils having high vanadium content. In closed-cycle plant tests of 200 hr. at about 1500° F. maximum tube temperature, tubes of a complex nickel-chromium-cobalt austenitic steel were completely perforated. The ash deposits contained approximately 80% vanadium as V_2O_5. An open-cycle gas turbine experienced blading attack after firing for about 300 hr. with a fuel oil that left an ash containing 25% vanadium as V_2O_5. The turbine inlet temperature was about 1200° F.

The author couples these observations with numerous laboratory tests and makes the statement that no heat resisting alloy is immune to even very small amounts of vanadium. Attack seems to begin at about 1100° F. and at about 1300° F. no material can be expected to have a life of more than a few thousand hours. It has been observed that complex nickel-chromium-cobalt alloys (such as G18B or Rex 326) are more readily attacked than high nickel alloys (Nimonic 80) or the standard 18-8 columbium or titanium stabilized materials.

During one run with the closed-cycle plant, carbon tetrachloride was added to the oil in an effort to volatilize the vanadium. This procedure did not produce an

(Continued on p. 128)

Gas-Turbine Materials

(Continued from p. 126)

improved result, and may have accelerated the attack. Other additives have shown more promise and experiments are continuing.

The author points out that designers encounter a "no man's land" between about 1025 and 1100° F. in the selection of materials for long life. Below this range, more or less standard ferritic steels are satisfactory, and above, austenitics are required. He emphasizes the need for improved ferritics so that it won't be necessary to overdesign by using austenitics in this range.

C. T. Evans, Jr.

Joining Metals With Resin Adhesives*

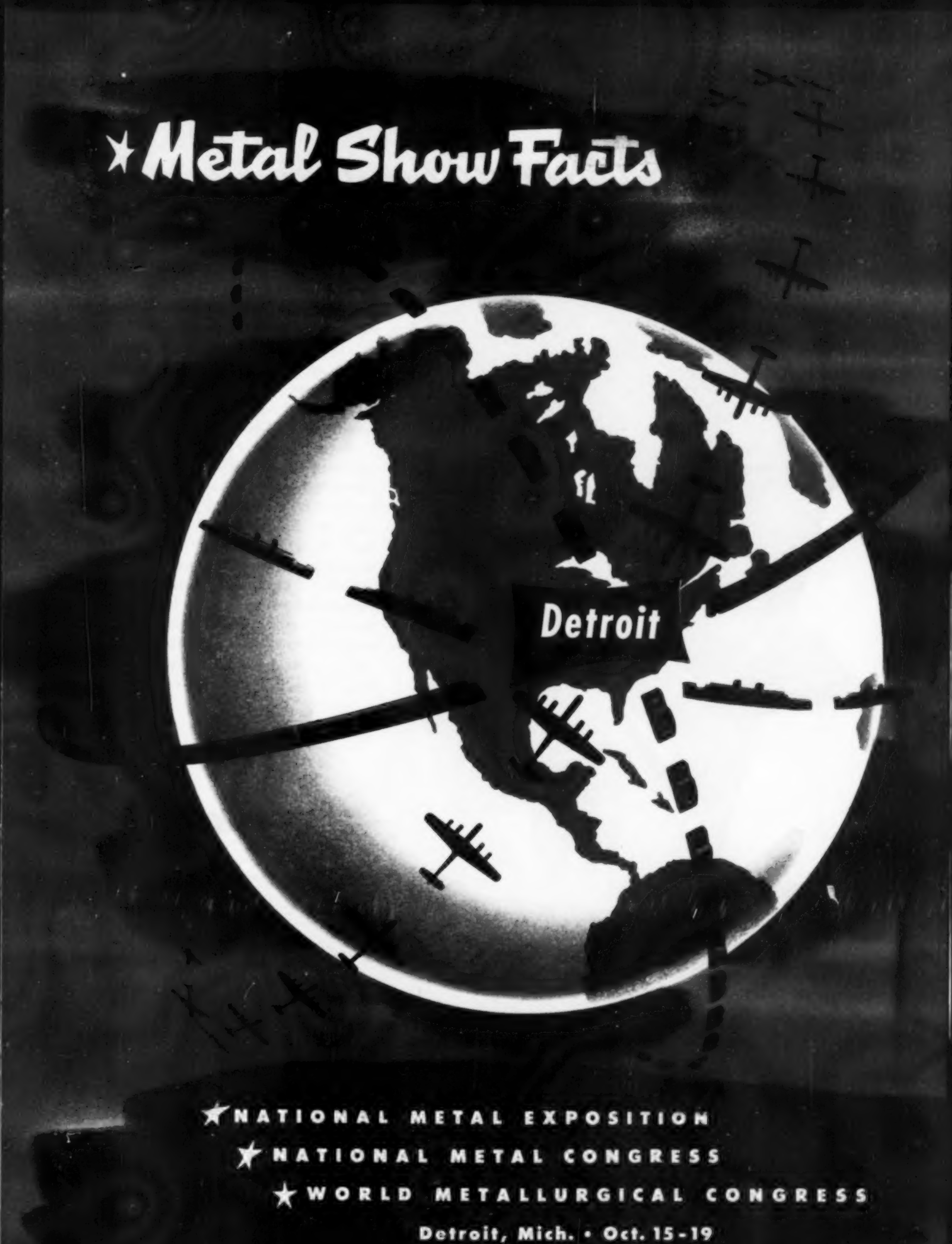
Bonding of metals with synthetic resin adhesives is compared with the older methods of fastening and while all these have their limitations, particularly in the case of heat treated aluminum alloys, synthetic resins are, in many instances, to be preferred, especially for light alloy work.

The chief recommendation for resins is that they may be easily changed from liquids, or from solids with low melting points, into hard infusible materials that are resistant to a wide variety of conditions including exposure to weathering, acids and alkalis. These phenolic resins may be prepared as viscous liquids which, with the help of suitable solvents, are brushed or sprayed on metals and then hardened by baking for a short time at 280 to 300° F. Hardening may also be made to occur without heating with the use of a suitable catalyst. Acids or acid formers may be used particularly with urea-formaldehyde resins. The use of acid formers, however, is not suitable with metal as corrosion takes place readily.

Reference is made to pressure welding to explain the formation of a satisfactory bond resulting from the forces of attraction when molecules of metal are brought into sufficiently close contact. Suitable resin adhesives, when applied to perfectly clean metal, may be looked upon as the filling-in of microscopic voids in the surface, with

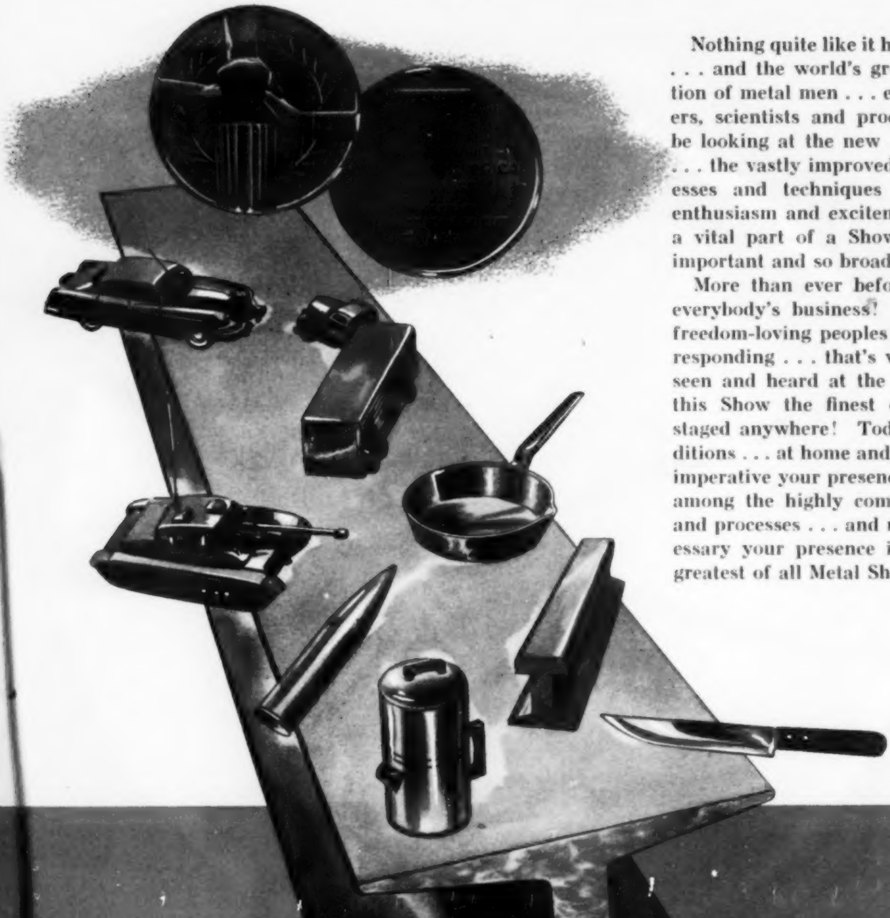
(Continued on p. 130)

*Abstract of "The Bonding of Metals", by C. J. Moss, *Metallurgia*, June 1951, p. 267-272.


★ Metal Show Facts
Detroit
★ NATIONAL METAL EXPOSITION
★ NATIONAL METAL CONGRESS
★ WORLD METALLURGICAL CONGRESS
Detroit, Mich. • Oct. 15-19

The 1951 Metal Show . . . soon to be the

Finest Show of its Kind on Earth!



Nothing quite like it has ever been seen . . . and the world's greatest concentration of metal men . . . engineers, designers, scientists and processors who will be looking at the new . . . the different . . . the vastly improved machines, processes and techniques will reflect the enthusiasm and excitement that become a vital part of a Show so big . . . so important and so broad in scope.

More than ever before . . . Metal is everybody's business! That's why the freedom-loving peoples of the world are responding . . . that's why what will be seen and heard at the '51 Show makes this Show the finest of its kind ever staged anywhere! Today's critical conditions . . . at home and abroad . . . make imperative your presence as an exhibitor among the highly competitive products and processes . . . and make doubly necessary your presence in person at this greatest of all Metal Shows!

Big Business

Whenever the nation's leading metal men take time off at the peak of production to congregate in ONE PLACE and to check on what's new . . . what's faster, better . . . to look purposefully into competitive fields and to spend a full week or more absorbing the fullest information on new techniques . . . you've got BIG BUSINESS.

The 45,000-plus metal men who will attend the 1951 Metal Show will be there on business . . . YOUR BUSINESS if you are an exhibitor and if you have your Show staff primed and trained to do a top-notch selling job! With today's world conditions demanding more and more production . . . with defense orders swinging into high gear and consumer demand sure to boom again with relaxed credit controls . . . the metal men of the nation and the world will be keenly interested in anything that will facilitate their production in an era of peak demand.

What's more . . . the new techniques and the new ideas you'll hear at the technical sessions will keep you abreast of competition and informed on the important changes the metal industry faces in the years ahead. You can't afford to miss . . . with your products or services . . . or your key men!

1951

SOLD is the word that keeps the metal industry moving . . . and that's the tag you'll see on a staggering volume of business directly started and closed at the '51 Metal Show.

Plan to follow up every sales lead that's sparked on your products or services at the Show! With more than 1,125 metal men per hour passing your exhibit . . . it'll be up to you and the stopping power of your display to get your share of the BIG BUSINESS that will be exposed to your sales efforts!

SOLD

The Metal Show has the Buyers!

Because the Show concerns itself with everything metal industry men *need* and *want* . . . because it is a specialized presentation . . . dramatic and colorful . . . to a specalized field it builds prestige and profit for every exhibitor . . . for every registered guest.

Measuring the impact of the Show itself on the metal industry men who make it their business to attend is a complex and difficult thing . . . but experience has proved that fact that long months after the Show itself is history—the *Show keeps right on selling* for those exhibitors who had what it takes in the way of products, processes or services. What they see, what they learn and what they take away with them is the key to the business that keeps right on piling up from the metal men . . . even repeat business that started with a purchase during the Show.

Exhibitors have learned much from experience, too. That's why the displays being prepared now for the '51 Show are smarter, snappier than ever before . . . that's why they've added motion, color and excitement to their displays. Good showmanship is good salesmanship and your exhibit, properly and attractively designed, will get you a share of the attention and the sales that are started at the Show.

A few good spots are still available and your reservation for this greatest of all metal shows ought to be on its way this very minute to assure your chance of bigger sales where the biggest group of metal industry buyers will be . . . Detroit, Mich., Oct. 15-19. There's no time to lose!

The Buyers will look First at the '51 Metal Show

- They'll want to see what's NEW
- They'll check on major improvements
- They'll ask about prices, deliveries
- They'll want detailed performance data
- They'll be interested in your sales story
- They'll look for production "boosters"
- They'll examine your products carefully
- They'll want to know about everything
- They'll judge your exhibit and interest
- They'll *buy* from exhibitors who *sell* them!

The Metal Show

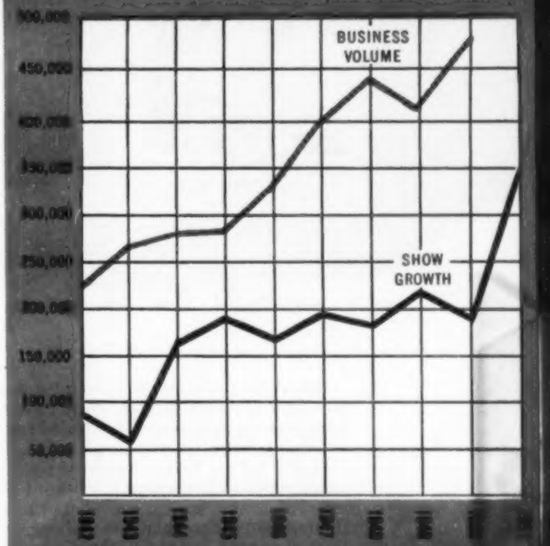
Good Business BAROMETER

NEW PEAKS OF DEMAND AHEAD AS DEFENSE AND CIVILIAN NEEDS POINT TO BUSY FUTURE . . .

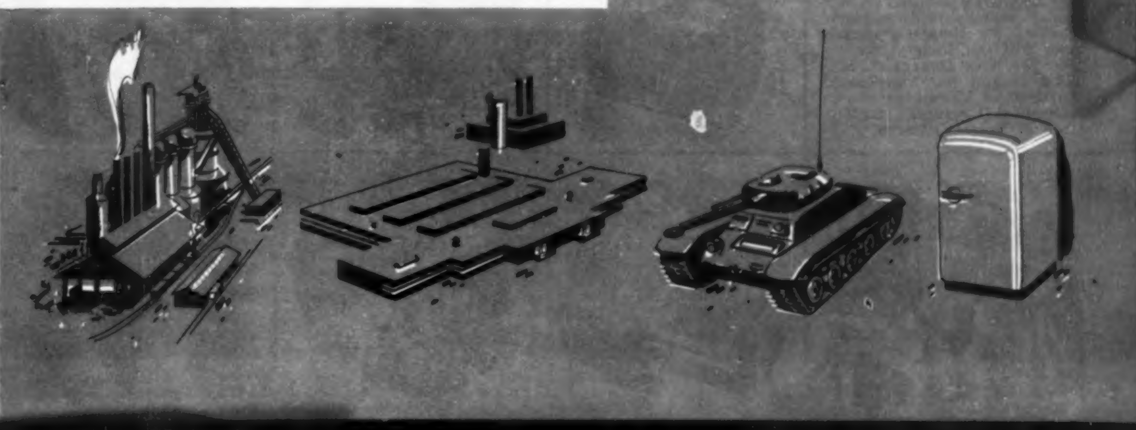
It's going to be a whale of a year . . . because it's going to be a whale of a Show. That yardstick works—and over the years when the Show has been big, bustling and packed with competitive products, it's meant a busy year for the metal industry. Right now this one figures to be the Show of Shows . . . in size, in scope, in impact on defense and civilian producers of things fashioned of metals.

As a business barometer, the Shows have reflected the moods of business everywhere—and this year there is every indication of booming production . . . sustained high sales and consumer markets to gladden the hearts of all alert manufacturers. Proof of that lies in the growing lists of exhibitors who want in on this greatest of metal round-ups—and the reasons expressed for demanding a spot in the "big league" Show. Those reasons vary from a sober realization that no matter what comes they'll have to fight for their markets . . . to a buoyant optimism over sustained good business.

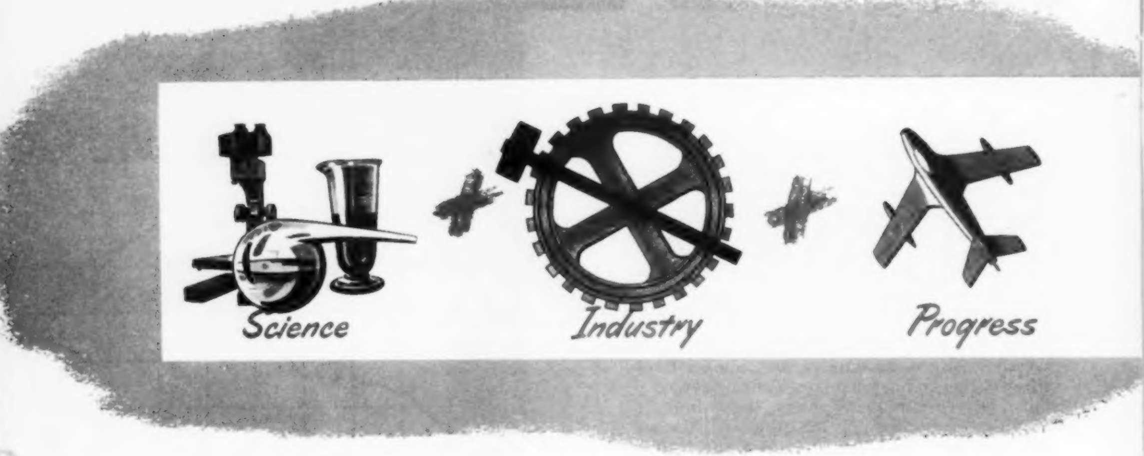
Beyond the market predictions of those exhibitors who sell to the metal industry lies the sound and proven need for retaining identity and product prestige in the Show itself. Long ago the wiser suppliers to the metal industry learned that it makes a lot of sense to be a remembered unit in the big parade of the metal industry!



The chart above shows the steady growth of the Metal Show over the post-war years and the growing demand for all things made of metal. A sharper upturn for the early months of '52 is indicated in the upturn of exhibitors showing in the '51 Show.



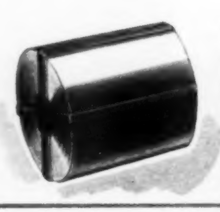
The National Metal Congress

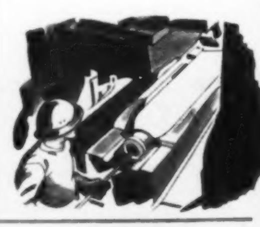


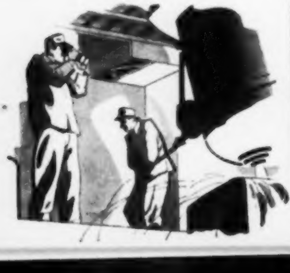
Want to know what's cooking for the metals you work with? Want to know about newly engineered formulas for metals that'll bend, shape, form easier, faster—that'll take a better finish or perform a specific job at lower cost? Without exposing what the metal scientists have up their sleeves for this vital phase of the Detroit events, it's a good guess that every man who works with metals will find the time spent at these sessions mighty helpful and maybe profitable, too, for the immediate months ahead.

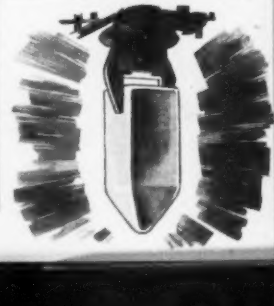
Conservation, substitution and best use of critical metal supplies are sure to get a thorough airing . . . as well as new ways of making metals behave under today's special needs. Plan your Show time to include the sessions of the Metal Congress and be sure your engineers and your key men are present to keep abreast of what's new and important in the frontier of metal development. Check your programs and make sure you don't miss the exciting, informative, educational hours planned for you!

The Metal Congress, as in years past, will feature the technical progress of the following national technical societies: American Society for Metals; American Welding Society; Society for Non-Destructive Testing and the American Institute of Mining and Metallurgical Engineers, Institute of Metals Division.









...The World Metallurgical Congress

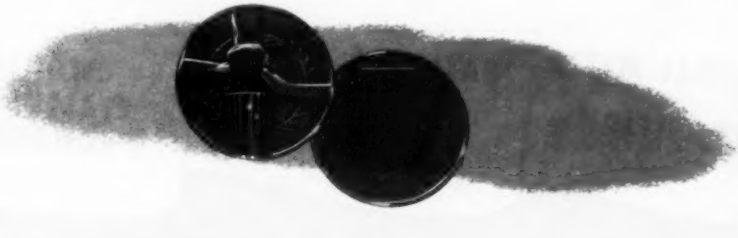
... the first event of its kind in all History

It has taken man endless centuries to reach the point where, for a common defense against a common enemy, he is willing to share with his neighbor the knowledge he has accumulated in the making and the development of weapons for defense.

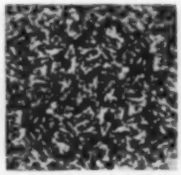
Now, for the first time in history, under the sole sponsorship of the American Society for Metals, free men from the free nations of the world will pool their resources . . . in arms, in manpower, in SCIENCE. What concerns the metal industry of America rests in the knowledge, the techniques and the conservation experiences that will be brought forth at the World Metallurgical Congress.

Because hundreds of foreign metal scientists will be present and because a natural reticence might make them a bit shy of open discussion with American metal industry men—it'll take a lot of that easy, solid good fellowship Americans have to make our guest scientists feel at ease . . . to feel at home. From these men Americans should learn much of production in times of critical shortages . . . for these men have worked and produced under severe handicaps and what they have accomplished should add measurably to our stock of knowledge.

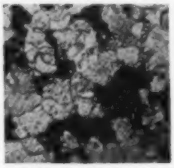
Facing a common enemy, the most precious weapon at our command is KNOWLEDGE . . . and to anyone who can help, by his experience and his scientist's hunger for accurate information—America should and will extend the courtesy of deep interest and encouraging response. So plan now to be there . . . plan to learn all you can from the scientists who have never had the advantages Americans consider routine in the development and production of weapons for defense!



How to select grain structures for better machinability of alloy steels

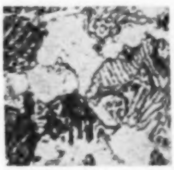


Sorbitic, Med. C



Blocky Ferrite, Low C

Spheroidized, Med. C



Lamellar, Med. C

The combination of grain structure, ductility and hardness has, in general, much to do with the degree of machinability of an alloy steel.

For purposes of comparing different types of machinability, all alloy steels may be grouped in three carbon ranges: low carbon, .08 to .30 pct; medium carbon, .30 to .50 pct; and high carbon of .50 to .80 pct.

Each of these ranges must be considered separately, as each has a pronounced effect on the corresponding grain structure and machining properties. Certain grain structures may be well suited for one type of machining and at the same time wholly unsuited for others. For example, in a medium carbon range, an alloy steel with a spheroidized structure may be good for turning operations, poor for forming, fair for drilling, and poor for broaching. This, of course, means that a compromise must usually be accepted to get the most economical overall machinability in any one grade of steel.

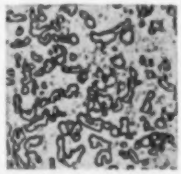
The table shown here is a suggested guide. It contains various combinations of carbon range, heat-treating process and structure believed to be most suitable for each type of machining.

Our metallurgists will gladly furnish further information on the relative machinability of various alloy grades. Call or write for this information.

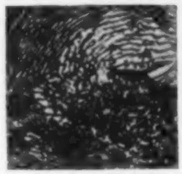
Bethlehem is a dependable source for all of the AISI alloy steels as well as the full range of carbon grades and special steels.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

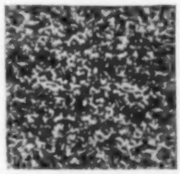
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation



Spheroidized, High C



Lamellar, High C



Sorbitic, High C

CARBON RANGE	PROCESS	STRUCTURE	TURNING	FORMING	DRILLING	BROACHING
LOW (C .08 to .30)	Normalize or Anneal	Blocky Ferrite	Good	Good	Good	Good
MEDIUM (C .30 to .50)	Anneal	Spheroidized	Good	Poor	Fair	Poor
MEDIUM (C .30 to .50)	Anneal	Lamellar	Fair	Good	Good	Good
MEDIUM (C .30 to .50)	Heat Treat	Sorbitic	Fair	Fair	Fair	Fair
HIGH (C .50 to .80)	Anneal	Spheroidized	Good	Good	Good	Fair
HIGH (C .50 to .80)	Anneal	Lamellar	Fair	Poor	Poor	Poor
HIGH (C .50 to .80)	Heat Treat	Sorbitic	Good	Fair	Good	Good

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL

Joining Metals With Resin Adhesives

(Continued from p. 128)

the result that the resin adheres to the uneven metal surface and the main base metal adheres to the resin.

Phenol-formaldehyde resin may be brushed on metal and a polyvinyl formal powder sprinkled onto the resin. This powder makes the glued joints tough but it does not "wet" the metals properly, even when subjected to heat and pressure. The thin coating of phenol-formaldehyde, however, wets the metal efficiently and is also a particle solvent for the polyvinyl formal. Together the two make an excellent metal adhesive. Rubber may be bonded to metal.

Glued joints are strongest in shear and are good for tension, but they should not be subjected to a "peeling" effect or the rolling back of one sheet of metal from another, which causes stress concentration in a narrow band. Resin glued joints have been made having a shear strength of 8800 psi., while a strength of 5000 psi. is obtained readily. One of the latest resin compounds, "Araldite", has given a strength of 10,000 psi.

HAROLD J. ROAST

Increasing Bessemer Production*

During a shortage of hot metal while a blast furnace was down for rebuild, oxygen from a driox station was used in one 28-ton converter to melt as much additional scrap as possible, because any additional scrap would increase the weight of gross metallic charge and thereby increase ingot tonnage.

Under normal operations in a charge of 60,000 lb., 4000 to 5000 lb. of steel scrap can be melted by using 4000 to 6000 cu.ft. of oxygen. The blowing time is shortened about 1 min. The blast used is 25,000 to 35,000 cu.ft. per min. at 25-30 psi. More than 2900 oxygenated blows have been made in which about 6000 additional tons of scrap have been melted using about 15 million cu.ft. of oxygen. The driox plant delivers about 600,000 cu.ft. of gaseous oxy-

(Continued on p. 132)

*Abstract of paper, "Oxygen as a Means of Increasing Bessemer Production", by W. G. McDonough, presented before the General Meeting of American Iron and Steel Institute, May 23-24, 1951.

A Stainless Job That Points to Success

for Your Future Products . . .

When your talk gets around to Stainless for your own future products, this Stainless job points the way to giving you extra advantages. It shows why it pays to consider Carpenter for Stainless that will do the unusual.

Take a second look at this job, for example. Tolerances were close, and had to be "on the nose" every time. Finishes had to be "perfect", to insure accurate operation. And like all other precision jobs, the parts had to be produced with minimum rejects.

In today's planning for the future, if you have the problem of recommending a Stainless that will give you something extra in performance or in production, it's a good idea to call Carpenter. Put Carpenter's experience with Stainless to work on *your* jobs.

Helping engineers get improved or unusual results with Stainless is our favorite job. From the time the first free-machining Stainless was invented in Carpenter's laboratories, we have been developing new Stainless Steels and improving old ones. They are described in "Working Data for Carpenter Stainless Steels". Let us know if you would like a personal copy.

The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Department: Carpenter Steel Co., Reading, Pa.—"CARSTEELCO"

DON'T WAIT... COOPERATE!
The U.S. Needs Your Steel Scrap, Now

Carpenter
STAINLESS STEEL
takes the problems out of production

Increasing Bessemer Production

(Continued from p. 130)

gen daily at a line pressure of 125 psi. of which 200,000 cu.ft. is available to the bessemer department.

The first six oxygenated blows were charged with 10,000 lb. of scrap compared with 5000 lb. used in the reference blows. Beginning 30 to 60 sec. after the start of the blow, 1500 to 2000 cu.ft. of oxygen was introduced for approximately 6 min. This resulted in 24.2% oxygen in the total blast consumed during the entire blow. All of the scrap melted, but the temperature was lower than in the reference blows.

Varying the amount of oxygen with the same scrap charge indicated that some oxygen was being blown through without reacting. A standard practice was developed using 4 min. of oxygen at 1500 cu. ft. per min. starting 2 min. after start of blow. The scrap charge was 2000 lb. less than double that used in the reference blow. After a few days the scrap charge was changed to an even 4000 lb. more than that used in the reference blow. The flame and pyrometer indicated nearly the same temperature for this practice as for the reference blows. Following further experimentation, the practice adopted was to use oxygen for 4 min. at 1000 cu.ft. per min. starting after the carbon flame.

In decreasing the oxygen per blow from 15,000 cu.ft. down to 4500 cu.ft., the additional scrap melted per thousand cubic feet of oxygen increased from 400 up to 1000 lb. Almost 1000 lb. of additional scrap can be melted per 1000 cu.ft. of oxygen with an upper limit of 5000 lb. additional scrap per blow. Using more than 4000 to 6000 cu.ft. of oxygen per blow wastes oxygen and impairs quality, yields, and cost.

Use of 3000 lb. of roll scale (which contains 825 lb. of oxygen) in a 60,000-lb. charge decreases the blowing time about as much as does 12,000 cu.ft. of oxygen which weighs 1000 lb. The roll scale chills the metal so that the scrap charge must be decreased 1000 lb. for each 1000 lb. of scale used. Most efficient use of gaseous oxygen is obtained with 1000 lb. of steel scrap or equivalent steam as a coolant for each 1000 cu.ft. of oxygen to offset the excess temperature developed. These results suggest the use of roll scale (if available) where the chief

(Continued on p. 134)

Increasing Bessemer Production

(Begins on p. 130)

concern is blowing time with an ample supply of hot metal; and a gradual replacement of roll scale with oxygen as the hot metal supply decreases, thus achieving the highest level of ingot production.

No pronounced effects have been found on bottoms or linings when using oxygen in the standard amounts now specified. The hotter flame keeps skulls from forming on the nose and decreases physical damage from their removal. Emphasis is placed upon the *judicious* use of oxygen to increase production in acid bessemer converters.

F. G. Norris

Relief of Stress in Cast Iron*

The effects of various annealing times and temperatures on the relaxation of stress in gray cast iron (for piston rings) are reported. The iron conformed to British Standard Specification 4K6 for aircraft materials and components and had the following analysis: Total carbon 3.37%, silicon 1.58%, manganese 0.98%, sulphur 0.095%, and phosphorus 0.78%.

Radially split rings were sprung open to a nominal gap width and maintained this way during annealing. The force necessary to maintain the constant gap width was recorded. The author reports a drop in stress during heating up to 750° F., the initial stress (whether 18,000 or 21,000 psi.) is reduced relatively little (about 15% at 750° F.) but beyond this temperature the stress is considerably reduced (about 80% at 1110° F.). Continued heating at temperature affects continued reduction in stress, although a limit to the reduction is reached eventually. At 750° F. this limit is approached at about 500 hr., at which point the initial stress is reduced about 45% at 1110° F. after 48 hr. (when the limit is approached) the reduction is about 92%. The strength of the rings was lowered by any heat treatment, about 10% at 750° F. and 15% at 1110° F.

W. M. Baldwin, Jr.

---

*Abstract of "The Relief by Heat-Treatment of Externally Applied Stresses to Cast Iron", by G. N. Gilbert, *Journal of Research and Development*, British Cast Iron Research Association, Vol. 3, August 1950, p. 499-506.

Structure of Electrolytically Separated Martensite*

In studying carbide particles that had been separated electrolytically from quenched steels, solid particles of alpha martensite were sometimes observed. This observation suggested the possibility of learning more about the processes of hardening and tempering steels by studying martensite that had been separated in this manner from the body of steel specimens.

For this purpose, carbon steels containing 0.80, 0.98, 1.16, 1.38, and 1.51% carbon were quenched from the austenite range. Aqueous solutions of hydrochloric acid or of potassium chloride and citric acid were used in electrolytically separating the martensite in these steels. X-ray diffraction patterns from the martensite residues so obtained were made using iron radiation, and comparison patterns were also made for solid specimens of the 0.98% carbon steel specimen.

Results of the electrolytic separation of the steels and the X-ray analysis of the resulting residues showed that a necessary condition for electrolytic separation of martensite is the presence of some retained austenite. The austenite has a higher solution potential than the martensite, and it is possible to cause the austenite to dissolve, thus freeing the martensite crystals.

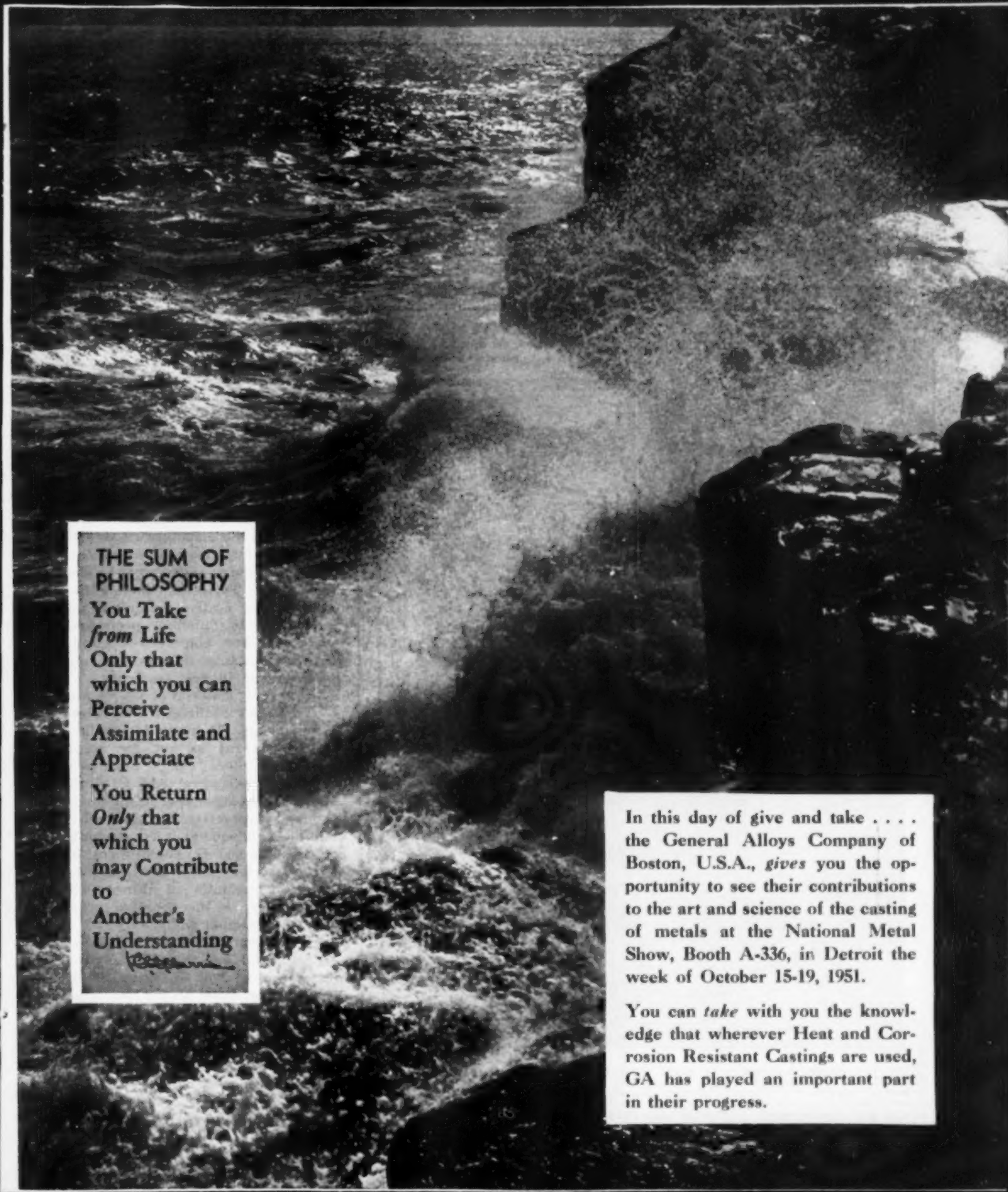
Comparison of the diffraction patterns from the residues and from the solid steel specimen showed that the essential difference between them was the more diffuse diffraction lines in the pattern from the solid specimen. This difference was accounted for on the basis that martensite crystals in solid steel are under elastic stress, and that these stresses are largely relieved when the martensite crystals are separated from the body of the steel.

The lattice constants of the martensite were, within experimental error, the same in the solid specimen as in the residue. This fact was interpreted as showing that the tetragonality of martensite is not caused by elastic stresses in the steel, but is a natural result of the mode of crystallization of the iron and carbon atoms.

A. G. Guy

*Abstract of "Structure of Martensite Separated Electrolytically from Quenched Steel", by M. P. Arbuzov, *Doklady Akademii Nauk SSSR*, Vol. 74, 1950, p. 1085-1087.

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite



THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

Turbine Materials and Performance*

Chief obstacles to rapid advance of large power gas turbines for long life are: *(a)* cost of materials and manufacture and *(b)* uncertainties as to dependability over extended periods of time (100,000-hr. design goal). Several ingenious charts are provided by the authors which relate inlet operating temperatures with performance and show the penalties involved in using ferritic steels for blading and rotors as opposed to the super-austenitic alloys, such as G18B and Nimonic 80A, currently in use. However, it is pointed out that in a complex gas turbine cycle which includes more than one stage of compression with intercooling and regeneration, higher turbine inlet temperatures cannot always be justified on the basis of better over-all performance.

The advantages of cooling the rotating blades are clearly shown in another chart. The authors demonstrate that blade root cooling, which is relatively easy to accomplish, does not, unfortunately, permit a large increase in turbine inlet temperature. Other types of cooling (such as by use of hollow blades with inserts) are much more promising but involve high manufacturing expense and operating uncertainties. Thus "sweat cooling" by use of pores distributed over the blade surface to provide a heat protecting layer of cooling air, channeled from within, would fail if the pores became clogged with impurities.

The statement is made that most large gas turbines are currently being manufactured with welded rotors, but there are many uncertainties in this method of construction. Accordingly, there is a real need for large, dependable, one-piece rotor forgings made with integral stub ends and flanges.

The blades are shown to be a high proportion of the cost of large gas turbines. The authors believe that the designers must accommodate their aerodynamic requirements to the use of simpler blade shapes and the metallurgists should try to provide a material which can be used in the as-rolled or as-forged condition. This may obviate the necessity for costly machining and grinding as finishing processes, which are now employed to eliminate intergranular fissures that may be produced in heat treating.

However, material problems are by no means confined to the rotating elements. There is no satisfactory material as yet for heat exchanger tubes where heat and corrosion resistance tend to work at cross purposes. Thus, aluminum-bronze is attractive corrosion-wise but lacks adequate creep strength above about 900° F. The first cost is also a serious consideration, because many miles of thin-walled tubing may be incorporated in a given heat exchanger.

It is reported that a 500-hp. experimental gas turbine has run for more than 3000 hr., using either heavy oil or diesel oil for fuel. Operating temperatures have rarely exceeded 1100° F. and blade corrosion has not yet been a problem, although fouling has occurred with the use of heavy oil and the ash analyses run from about 35.0 to 62.0% vanadium as V_2O_5.

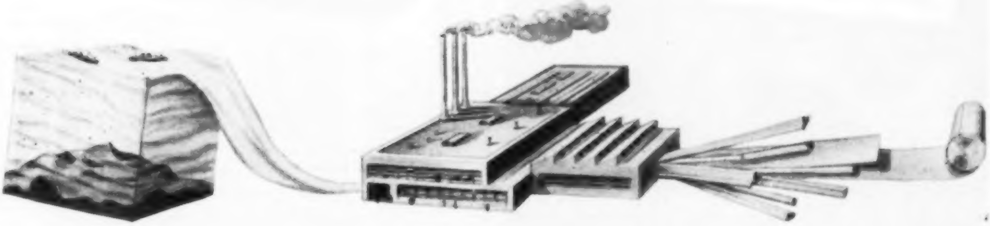
C. T. Evans, Jr.

*Abstract of "Materials and Performance", by A. T. Bowden and W. Hryniszak, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 11-17.

MAGNESIUM

and the problem of

METAL SUPPLY



for your product

The problem of metal supply is in reality a dual problem. First is the question of raw material supply and second, the supply of fabricated forms. To each of these, magnesium offers an interesting answer.

As the increased demands of industry call for more and more metal from Mother Earth, ore reserves become ever more important. Magnesium metal, now extracted from the sea, is the one metal with literally an inexhaustible supply. Consider this fact:

If magnesium were extracted from the sea at the rate of 100 million tons per year . . . the current rate of iron and steel production . . . for 1,000,000 years, we would have reduced the supply in those seas only from 0.13% to 0.12%!

And those seas are at our very shores, eliminating the costs and hazards of transportation. Here is a potential of interest to every metal user.

At the other end of the supply problem is the question of fabricated forms. Currently, Dow is constructing an 84" hot and cold sheet and strip mill, the first in this country for magnesium. When completed, this mill at Madison, Illinois, will increase Dow's capacity for sheet, plate and strip by many times . . . with provision for even further expansion. This new Dow mill will also have facilities for extrusion, increasing present capacity appreciably.

Metal supply? Keep your eye on magnesium . . . the world's lightest structural metal . . . offering you the potential of infinite supply.

For Your Product . . . Tomorrow!

Magnesium's perfect combination of light weight and high strength makes it invaluable to our defense effort. "Drafted" today, it still deserves every consideration in planning for your tomorrow's product. Wherever a product is made to be moved or lifted, magnesium is a *must.* 75% lighter than iron, 30% lighter than aluminum, magnesium is the world's lightest structural metal.

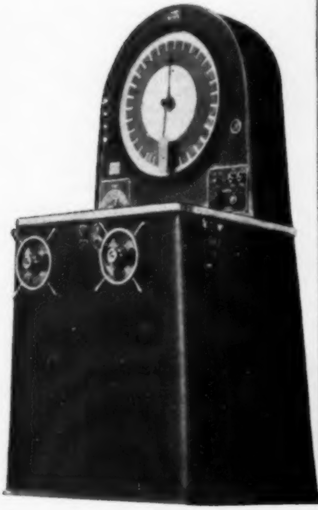
THE DOW CHEMICAL COMPANY
Magnesium Department • Midland, Michigan

New York • Boston • Philadelphia • Washington • Atlanta • Cleveland • Detroit • Chicago • St. Louis
Houston • San Francisco • Los Angeles • Seattle • Dow Chemical of Canada, Limited, Toronto, Canada

This Nation-wide Testing Organization

Gets the facts with

BALDWIN TESTING EQUIPMENT



These six B-T-E Universal Testing Machines are part of a single order built for Pittsburgh Testing Laboratory.

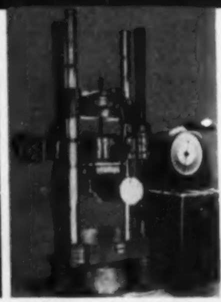
Because Industry recognizes the "high cost of ignorance" in design and construction, the Pittsburgh Testing Laboratory has built its fact-finding activities into one of the largest independent testing organizations in the country.

From its five-story headquarters in Pittsburgh, P.T.L. operates a chain of 23 industrial laboratories serving practically every important industrial center, and covering almost every field of testing and inspection.

Equipment includes scientific apparatus of the most modern types—with Baldwin testing equipment very well represented. Baldwin-Tate-Emery Universal testing machines of large capacity are installed in 13 branches. SR-4® gages and devices are extensively used, as are miscellaneous Baldwin accessories.

Whether you are setting up a small routine testing laboratory, or a full scale facility, you'll find a complete answer to your equipment needs in Baldwin's complete line. Write us your interest—we'll send literature.

Eddystone Division
Baldwin-Lima-Hamilton Corp.
Philadelphia 42, Pa.



A 300,000 lb. B-T-E Universal Machine and Baldwin SR-4® strain gages team up for a traveling block and hook assembly test in Dallas.

Testing a four-way strain band used for lumber on a 300,000 lb. B-T-E Machine in the P.T.L. San Francisco Branch.

Determining modulus of elasticity of concrete on a 300,000 lb. B-T-E Machine in the Buffalo Branch.

Here a 300,000 lb. B-T-E Machine in the Houston, Texas, Branch is testing a snatch block.

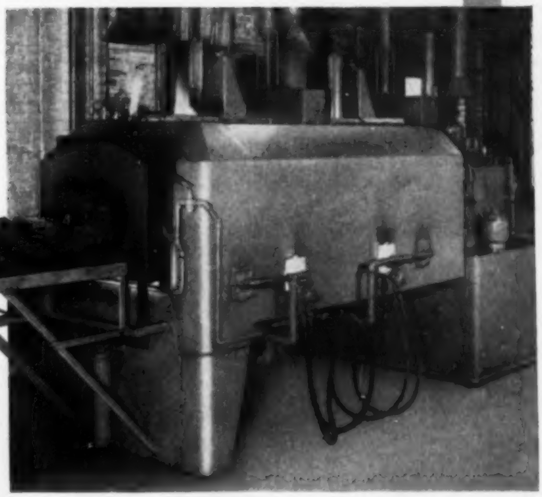
TESTING HEADQUARTERS

BALDWIN-LIMA-HAMILTON

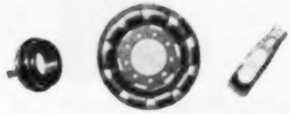
GENERAL OFFICES, PHILADELPHIA 42, PA. OFFICES IN PRINCIPAL CITIES


ROUND AND SHAPED TUBING
.010" to 5/8" O.D. Max. Certain Analyses .035" max. wall to 1 5/8" O.D. Available in:
Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095
Alloy Steels:
A.I.S.I.—4130, 4132, 4140, 4150, 8630, E-52100
Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5
Nickel Alloys:
Nickel, "D Nickel"*, "L Nickel"*, "Monel"*, "K Monel"*, "Inconel"*, 30% Cupro Nickel, 18% Nickel Silver.
Beryllium Copper.
THE HOLE STORY
by Superior
Chapter 3
The Kink That Takes the Kinks Out of Tubing
In the machine above, a length of tubing is shooting through a row of teeth. It will emerge straight as an arrow—ready for any tough job tubing can do.
Why all this fuss? Because whether our customers use Superior tubing as tubing or thread it, flare it, bend it, flatten it, they want to start with a straight piece to avoid misalignment or poor machining at any stage of operation.
In short, when a customer gets small tubing from us he expects tubing that is mechanically perfect as well as dimensionally precise and metallurgically sound. And he gets it.
We have many ways of insuring adherence to superior standards in all three. Frequent sampling for chemical analysis and microscopic examination checks metallurgy. Close visual and instrumental inspection at every stage of handling insure dimensional precision and mechanical perfection.
Because of Defense Orders, shortages of metals and other conditions beyond our control, we may not be able to supply all of your requirements for fine, small tubing but it will pay you to specify Superior. Your distributor may be able to fill your order out of stock.
Superior Tube Company, 2008 Germantown Ave., Norristown, Pennsylvania.
West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.
Superior
THE BIG NAME IN SMALL TUBING
All analyses .010" to 5/8" O.D.
Certain analyses (.035" max. wall)
Up to 1 5/8" O.D.

IPSEN FURNACE *plus ElectroniK* CONTROL
saves production time and reduces handling of
ROCKFORD CLUTCH PARTS



Dual control panels (one for each hearth) keep the furnace under rigid control.



AT THE Rockford Clutch Division of Borg-Warner, where nothing is permitted to interfere with quality, consistently high production is maintained through the teamwork of an Ipsen Furnace and Quenching Unit with two chamber hearths and *ElectroniK* Strip Chart Controllers.

The furnace is used for carburizing truck and tractor clutch parts, which are automatically transferred from the carburizing to the quenching chamber. Equipped with *ElectroniK* control, the unit effects substantial savings in the handling of continuous production runs and assures bright, scale-free work.

Only three operations are required in this modern installation: (1) loading of work hauling baskets; (2) pressing a starter button; (3) unloading. The run for each batch of work pieces is a precise duplication of previous runs.

ElectroniK Controllers are providing the same accuracy and precision throughout industry. For a discussion of your utilization of *ElectroniK* control, call in our local engineering representative . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa.

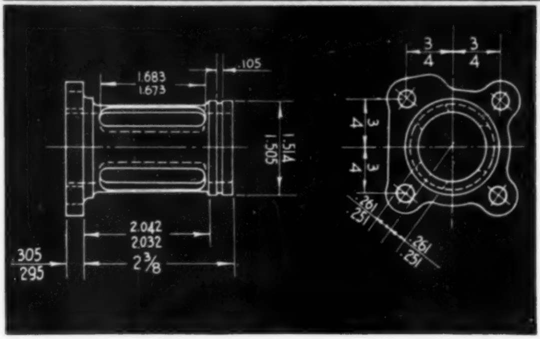
MINNEAPOLIS
Honeywell
Brown Instruments

ACCURATE CARBON DETERMINATIONS
Every 2½ Minutes!
The Fisher Induction Carbon apparatus is the modern self-contained unit for determining carbon in metals quickly and accurately. When used with the Gram-atic Balance, carbons may be determined every 2½ minutes!
A press of the button starts a cycle which includes the automatic regulation of the flow of gas, the preheating and complete burning of the sample, and automatic shut-off.
Interested in cooler laboratory, lower power consumption, greater precision and accuracy, faster results—automatically?
Write for details on the Fisher Induction Carbon apparatus!
Fill In Attached Coupon and MAIL IT TODAY!
FISHER SCIENTIFIC COMPANY
717 Forbes St., Pittsburgh 19, Pa.
Gentlemen:
Please send me complete information about the Fisher Induction Carbon apparatus.
NAME
COMPANY
ADDRESS

MISCO *Precision* CASTINGS

CARBON AND STAINLESS STEEL

CAST TO MICROMETER TOLERANCES



Part:

AIRCRAFT CARBURETOR METERING VALVE

Alloy: Misco 18-8
(A.M.S 5640)
Weight: 7.06 oz.

Misco Precision Castings make possible quantity production of pieces such as this which would be costly to attain by usual machining methods.

Types of parts which can be processed at a saving by the Misco Precision Casting Process cover a wide range. The Misco Precision Cast stainless steel aircraft part shown weighs 7.06 ounces as cast. Produced to the most rigid aircraft material specifications this piece was formerly machined from bar stock weighing three pounds. Here is a saving of 84% in weight of scarce metal alone and a more considerable economy in machining time. Castings of intricate design, close tolerances, with radiographic and metallurgical control, are obtainable from Misco in alloys ranging from carbon steels and stainless steels to non-forgeable super-alloys for use in high temperature jet aircraft applications. Misco, a pioneer producer, offers extensive technical experience in design, production and application of small precision cast alloy steel parts.

PRECISION CASTING DIVISION
Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys
1998 GUOIN STREET · DETROIT 7, MICHIGAN

. . . serving you since '32

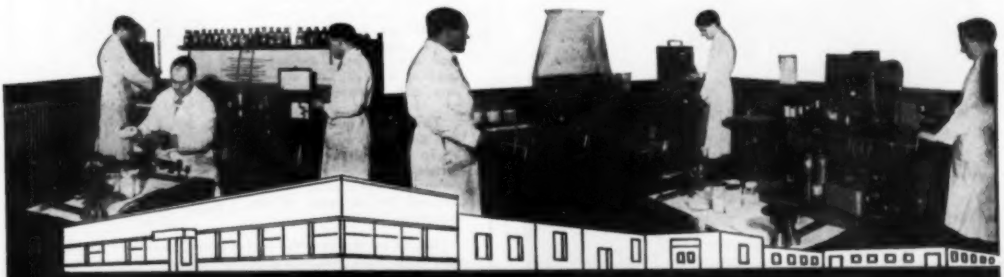
including the years of the Emergency, too

During the Last Emergency, we were vendors and consultants to many of the largest prime contractors producing material for the Army and Navy. . . . Our products were concerned with aircraft frames, aircraft motors, guns and gun parts, bombs and bomb parts, small arms, ammunition, brass and steel shell cases, automotive and tank parts, radio and radar equipment, electrical equipment, Diesels, machine tools, screw machine products, wartime appliances and caskets.

Our products were used for cleaning and drawing of aluminum, magnesium, brass, copper, steel and zinc prior to plating, bonderizing, anodizing, zinc chromating, painting, spot welding, heat treating, blackening, vitreous enameling and stripping. . . . The Northwest and Alkalume trade-mark was a familiar sight in hundreds of plants throughout the country.

Today, as the country is tooling for many of these same products, we are just as ready to serve—NORTHWEST has kept pace and has anticipated industry's every need in our field. . . . Our production facilities have more than doubled in the last five years and so has our technical staff. . . .

Our business has grown spectacularly during the present era because it has made sense to a lot of you to have the same company supply the correct lubricant for drawing metal and provide the product or process for its removal afterward. . . . *Let our technicians consult with you on your drawing and cleaning problems. You'll find it pays.*

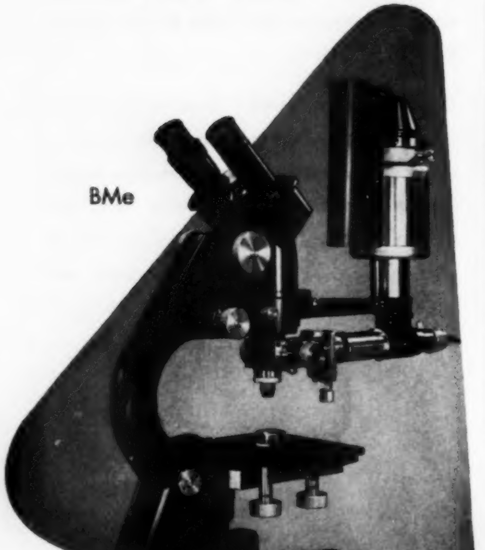


LO-HI pH

NORTHWEST CHEMICAL CO.

9310 ROSELAWN DETROIT 4, MICH.

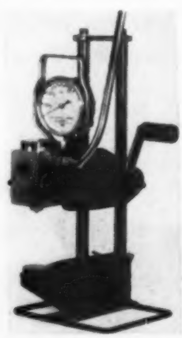
pioneers in pH cleaning control — serving you since '32



Pipe Burners

Nozzle Burners

King Burners



Throat—4" deep. Gap—10" high. Weight—26 lbs.

Metal Progress

Taylor Lyman, *Publisher*

A. P. Ford, *Sales Manager*

George H. Loughner, *Production Manager*
7301 Euclid Ave., Cleveland 3—UTah 1-0200

Harry L. Gebauer and John F. Tyrrell, *Eastern Managers*
55 W. 42nd St., New York 18—CHickering 4-2713

Ralph H. Cronwell, *Western Manager*
482 Burton Ave., Highland Park, Ill.—Highland Park 2-4263

Don Harway, *Pacific Coast*
1709 West 8th St., Los Angeles 14—DUnkirk 2-8576

PUBLISHED BY AMERICAN SOCIETY FOR METALS, 7301 EUCLID AVE., CLEVELAND 3, OHIO—W. H. EISENMAN, SECRETARY

Index to Advertisers